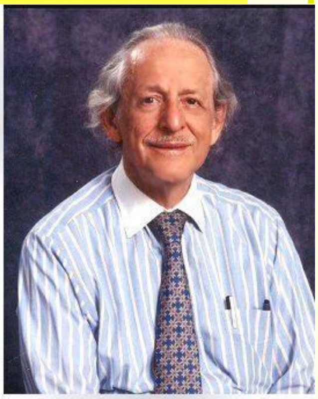
Grandfather of GOOGLE

Prof Dr Eugene Garfield

http://www.garfield.library.upenn.edu/

"I think you're making history, Gene!" So said Nobel laureate and molecular biologist Joshua Lederberg to his friend Eugene Garfield in 1962. They were building the Science Citation Index (SCI),



Tricennial Year [2023-2024]

Faculty of Management Studies

Dr. M.G.R.
EDUCATIONAL AND RESEARCH INSTITUTE
DEEMED TO BE UNIVERSITY
University with Graded Autonomy Status
(An ISO 21001 : 2018 Certified Institution)
Periyar E.V.R. High Road, Maduravoyal, Chennai-95. Tamilnadu, India.

Prof Dr Eugene Garfield

Grandfather of GOOGLE

Compiled by:
Prof Dr S Ramalingam
Joint Registrar - Languages

Details of Papers & Publications (1954 - 2009)

Papers : 1501	Citations:
Single-authored 1443	Total citations 5746
Multiple-authored 58	Highest citation 768 (Single Paper)
First-authored 1474	
Other-authored 27	

Global Publications = 1501

USA 1489
Russia 6
Italy 2
UK 2
Australia 1
Netherland 1

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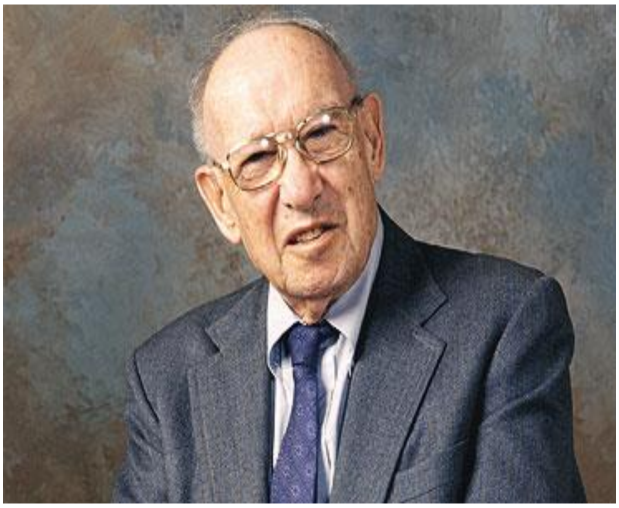
Peter Drucker



19 Nov 1909 <::> 11 Nov 2005

https://www.britannica.com/biography/Peter-F-Drucker

https://www.drucker.institute/perspective/about-peter-drucker/

FOREWORD

Eugene Garfield, a pioneer in the field of library and information science, founder of the Institute for Scientific Information and creator of the Science Citation Index, passed away on 26 February 2017.

He had a talent for seeing how what we would now consider to be primitive computer technology could be applied to solve large scale information problems. This was particularly true in his proposal for a citation index for science. In effect, he was able to find an engineering solution to an information problem, using punch card technology to store and manipulate the data records.

Dr. Eugene Garfield, the founder of ISI, devoted years to fulfilling his dream of creating a multidisciplinary citation index. The development of the *Science Citation Index* represented a fundamental breakthrough in scientific information retrieval. What began as a commercial product—a unique resource for scientists, scholars, and researchers in virtually every field of intellectual endeavour—has evolved into a sophisticated set of conceptual tools for understanding the dynamics of science. The concept of citation analysis today forms the basis of much of what is known variously as scientometrics, bibliometrics, informetrics, cybermetrics, and webometrics. Garfield's invention continues to have a profound impact on the way we think about and study scholarly communication.

I am happy to note that the Faculty of Management Studies has been associating themselves with Prof Dr Eugene Garfield for more than a decade. In 2012, they published a book, "Publishing a Research Paper"

and the book was dedicated to Prof Dr Eugene Garfield. Also, the book contains two chapters covering the very important technical aspects closely related to Prof Dr Eugene Garfield. Again in 2018 [the Silver Jubilee Year of the Faculty of Management Studies], a book on "Publish or Perish", was published, the first chapter being 'Eugene Garfield – Grandfather of Google'.

The present book, "Prof Dr Eugene Garfield – Grandfather of Google" covers several details / information relating to his life, contributions, research activities instituted in his name, his interviews on various occasions/topics and especially his PhD Thesis. The variety of information/details with the respective web links would be found very useful by all research scholars, faculty members, publishers of research papers/articles and other stakeholders in their activities in advanced research.

I do appreciate the Faculty of Management Studies in releasing the book during the its 'Tricennial year" (1993-2023) and dedicating the book to Dr Peter Drucker, the Management Guru.

Dr AC Shanmugam
Founder-Chancellor
Dr MGR Educational and Research Institute
Maduravoyal, Chennai – 600 095

Preface

On February 26, 2017, the world of information and library science lost one of its true pioneers with the passing of Dr. Eugene Garfield at age 91. His innovations – most notably, the *Science Citation Index* (*SCI*) – transformed not only the indexing and retrieval of scholarly literature, but the use of citations to track the dynamics of growth, concentration, and influence in the world of knowledge itself.

Although originally trained as a chemist, Garfield soon realized that his aptitude and inclinations lay in the direction of cataloguing information. This revelation was driven home during his initial employment in a chemistry lab at Columbia University, where he acquired a certain notoriety for causing explosions at the bench but found himself absorbed by the task of creating an index for the lab's store of newly synthesized chemical compounds. His course as an information scientist and entrepreneur was set.

Coming from humble origins, Garfield was truly a self-made man. One of his first products, *Current Contents*, had its origins in a converted chicken coop, where Garfield himself labored over a second-hand printing press. Like many successful inventions, the idea was astoundingly simple: Reproduce the contents pages of journals, thereby saving scientists and scholars the time and effort – decades before the internet – of going to a library to view the journals by hand in order to keep up with the latest research in their fields.

A weekly booklet, designed to fit easily into a lab-coat pocket, *Current Contents* ultimately expanded to multiple editions that covered all areas of science. It was the original flagship product at the Institute for Scientific Information (ISI), the company that Garfield founded in Philadelphia in 1955.

That same year, Garfield published a paper in *Science* expounding on his idea for an index to scientific literature based on citations. The existing, conventional indexes of the day relied on the subjective judgment of professional indexers, whose work was necessarily slow and who generally lacked detailed knowledge of the specialties involved. Garfield, by contrast, envisioned an index in which scientists themselves would function as his "army of indexers," creating subject linkages when writing their own papers and engaging in the compulsory practice of footnoting pertinent, related research.

Garfield grasped that these footnotes – each an acknowledgment of intellectual debt to previous research – would create cognitive connections that would be traceable and quantifiable. This thread of citations could demonstrate the progression, not to mention the influence, of a given finding or advancement.

Garfield's chief inspiration, as he readily acknowledged, was actually borrowed from legal literature and one of its key resources: *Shepard's Citations*. This extensive reference

permits a reader to track a given legal case and see if the decision was affirmed, overturned, or otherwise cited in subsequent cases. Garfield recognized that science, like law, proceeds on the basis of precedent, with researchers acknowledging and building on work that came before.

For Garfield, a central challenge in realizing his index was marshaling the necessary computational power – at that time, dependent on a bulky mainframe machine and the manual coding of punch cards. To track a given report's cited and citing papers, Garfield and his colleagues devised the means to code the necessary data into the 80 columns of a standard IBM punch card.

ISI released the *SCI* in 1964. More than 50 years later, its original multi-volume book format long since replaced by the online *Web of Science,* Garfield's index now covers more than 30,000 source publications and has amassed upwards of 1 billion cited references. And, as Garfield predicted, the tracking of publication and citation data spawned a specialty area of its own. Known variously as Scientometrics, Bibliometrics, or Informetric***s***, this branch of inquiry seeks to explore the shifting landscape of knowledge, tracking the growth and evolution of science and marking prominent points of influence. Another of Garfield's innovations, *Journal Citation Reports (JCR)*, works this vein, annually recording the most influential journals in their respective fields as measured by a citation-based metric, the Journal Impact Factor.

Despite ceding control of ISI in the early 1990s (the company, after a long stretch as part of Thomson Reuters, is now an independent firm known as Clarivate Analytics), Garfield remained active in information science. He developed a citation-based tracking and visualization program called HistCite. And, even while closing in on his 90th birthday, he was contributing refinements to *JCR* metrics. More than a half-century after he initially proposed them, Garfield's citation index and other innovations continue to aid the process of research and illuminate the global pursuit of knowledge.

Faculty of Management Studies [FoMS], during the Tricennial year [2023-2024], brings out this book honouring the "Grandfather of GOOGLE", Eugene Garfield [1925 – 2017], containing 29 chapters. FoMS has been associated themselves with Eugene Garfield by publishing books/articles on/about him from the year 2012. The complete details of this association have been provided in chapters 1,3, 6 and 7.

Several international organizations have established award, scholarship, etc., All these have completed covered with the detailed information. They are: Doctoral Dissertation Competition (chapter 8), Doctoral Dissertation Scholarship (chapter 9), Eugene Award for Innovation in Citation Analysis 9chapter 10) and Eugene Garfield Research Fellowship (chapter 11).

Chapter 13 provides a list of articles/papers/essays written by him between 1952 and 2011 with the corresponding web links. Chapter 14 contains a list of 100 Journals with their **H**ighest **I**mpact **F**actor [HIF]. His several innovative contributions have been

covered, thus: **S**cientific **C**itation **I**ndex (chapter 16), **I**nstitute of **S**cientific **I**nformation (chapter 17), **W**eb **o**f **S**cience (chapter 20) and The Scientist (chapter 22). Chapter 25 covers his 82 interviews given on various occasion/topics which could be reached by using the given web links. Chapter 19 offers the complete details about conferring the Honorary Degree to him by University of Barcelona on 14 June 2016. Chapter 27 provides three web links through which one can reach Indian Journals covering Scopus-indexed and/or in Web of Science, & UGC CARE list.

Chapter 28 [Annotated Webliographies] is a speciality, containing a highly selected and important 24 web links covering the various aspects of publishing, journal impact factor, science citation index, contributions of Prof Dr Eugene Garfield to information science, etc.,

FomS hopes that this simple and small attempt would benefit the young research scholars, supervisors and also, all other stakeholders in research.

Faculty of Management Studies feels very much grateful to our Founder-Chancellor for having consented and provided a Foreword to this book.

Prof Dr S Ramalingam
[Author]

Contents

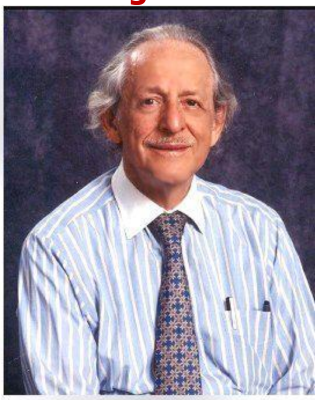
http://www.garfield.library.upenn.edu/

Silver Jubilee Year Publication

A Book: *Publish or Perish*

- The Faculty of Management Studies had published the cited book in 2018 (Silver Jubilee Year).
- Dedicated to and released on the eve of Birthday of our Founder-Chancellor (25 Sep 2018)
- The book contains chapters written by the staff of the Faculty of Management Studies.
- The first chapter is: **"EUGENE GARFIELD – GRANDFATHER OF GOOGLE"**

Prof Dr Eugene Garfield



16 Sep 1925 <::> 26 Feb 2017

'Grandfather of Google'

"Garfield came to see the impact factor as a mixed blessing, 'like nuclear energy'. Although he felt that citation indexing and the impact factor could be remedies for the limitations of peer review, he was uncomfortable with their misuse as performance indicators."

Here is the Chapter!

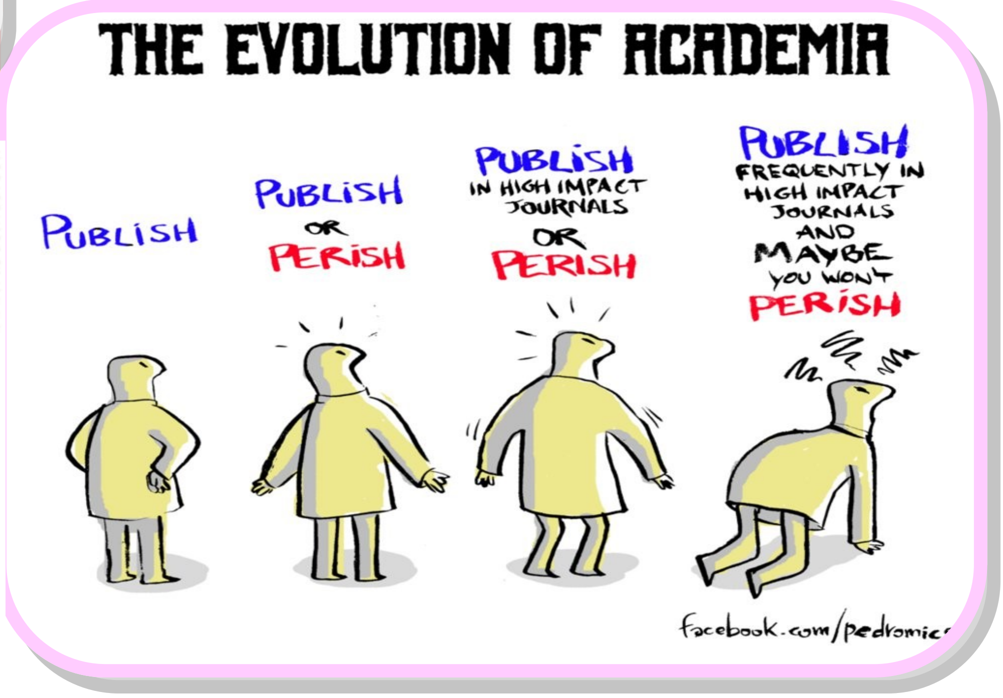
On the Eve of Founder-Chancellor's Birthday !

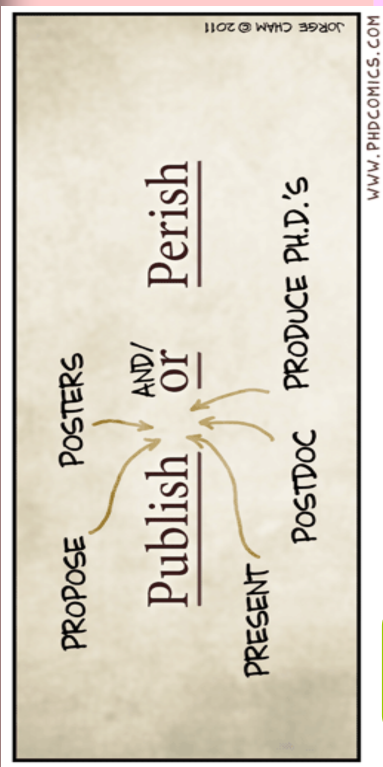
Silver Jubilee Year (1993-2018) of Faculty of Management Studies

'Publish or Perish'

Eugene Garfield

Grandfather of Google





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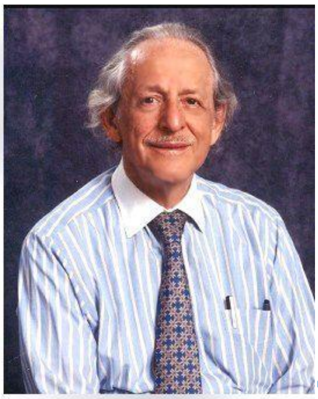


1925 2017

Prof Dr Eugene Garfield

Father of 'Citation Index'
Grandfather of Google

Dr. Eugene Garfield is the founder of the Institute for Scientific Information (ISI) and a pioneer in the field of citation analysis.

Eugene Garfield was one of the most influential figures in the world of library and information science in the second half of the 20th century. He pioneered citation indexing in the sciences and scholarly journal literature, in which the cited references (footnotes) in each article are recorded and serve as connections between papers, creating a network of ideas and concepts that can be navigated backward and forward in time. The first Science Citation Index was produced in 1964, nine years after he published the concept of citation indexing for the sciences in 1955. The Science Citation Index (now called the Web of Science) revolutionized the way people searched for information of interest. Garfield anticipated -- by 40 years -- the advent of hyperlinked pages on the web and the appearance of the Google Search algorithm (the patent for which cites Garfield). It took that long for technological developments to catch up with Eugene Garfield's vision. He founded the Institute for Scientific Information (ISI) in Philadelphia in 1960, which produced many databases and information products for libraries, universities, government agencies, and industrial firms worldwide. His firm was acquired by Thomson Corporation in 1992 (which eventually became Thomson Reuters),

Garfield came to see the impact factor as a mixed blessing, "like nuclear energy". Although he felt that citation indexing and the impact factor could be remedies for the limitations of peer review, he was uncomfortable with their misuse as performance indicators.

Garfield's enthusiasm was not the bookkeeper's but the visionary's.
He saw in his creations a better science for society and
the ideal of a unified body of knowledge accessible to all.

The following Figures speak for themselves

Garfield's personal profile page in Scopus

Garfield,Eugene

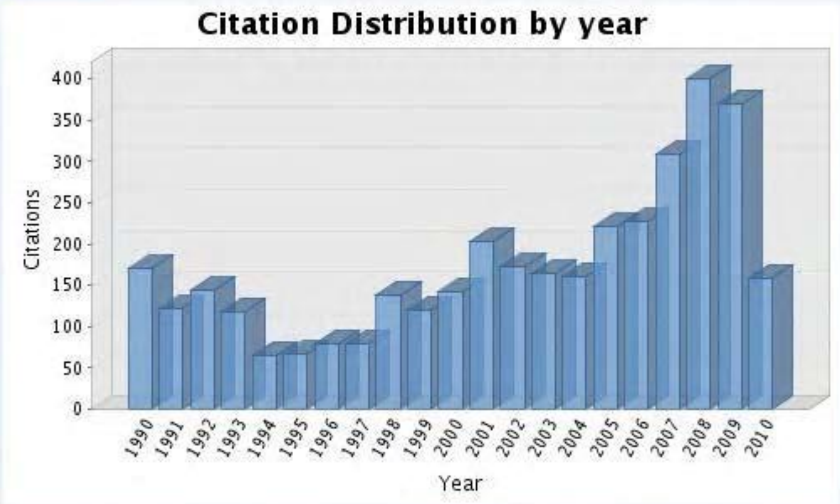
Find unmatched authors | Feedback | Print | E-mail

Personal						
Name	Garfield, Eugene					
Other formats	Garfield, E. GARFIELD, E.					
Author Identifier	7005088140					
Affiliation	ISI			Philadelphia United States		
209 documents have been added to your temporary List.						
Research	Garfield, Eugene			Total including 4 grouped Authors		
Documents	205	Add to list	E-mail alert	209	Add to list	E-mail alert
References	619			619		
Cited By	1643	Citation tracker	E-mail alert	1645	Citation tracker	E-mail alert
h Index	14	*h*-graph		14	*h*-graph	
	The *h* Index considers Scopus articles published after 1995.					
Co-authors	59			61		
Web Search	53279			53279		
Subject Area	Multidisciplinary Computer Science Medicine More...					

Garfield's ResearcherID badge on May 8, 2010

Publication List: Citation Metrics

This graph shows the number of times the articles on the publication list have been cited in each of the last 20 years. Note: Only articles from ISI Web of Knowledge with citation data are included in the calculations. More information about these data.



Total Articles in Publication List: **1528**

Articles With Citation Data: **1528**

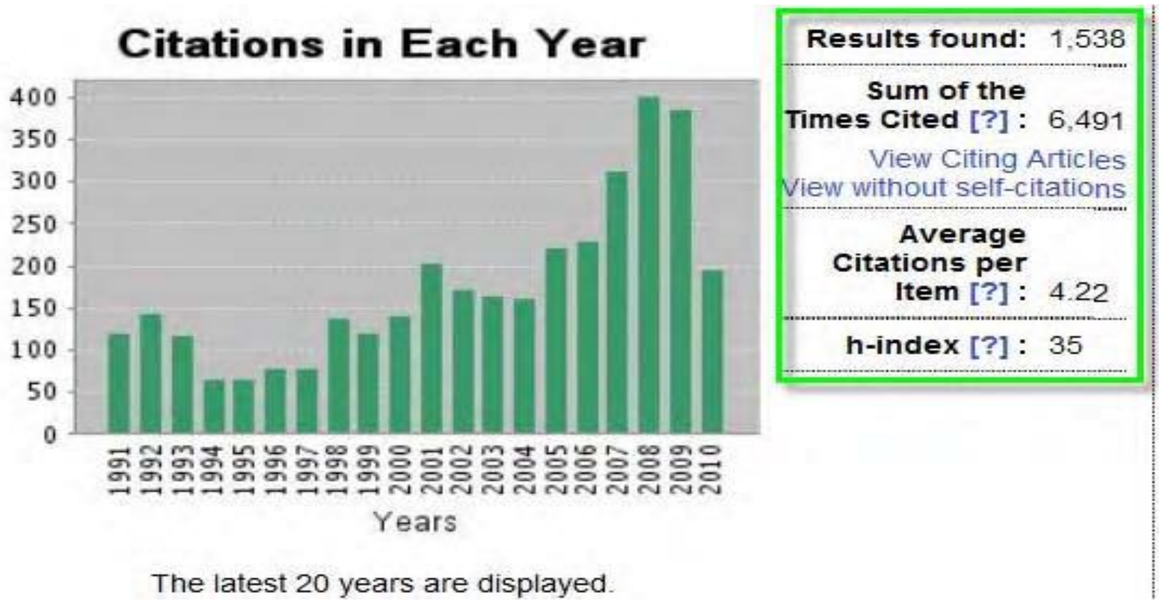
Sum of the Times Cited: **6429**

Average Citations per Article: **4.21**

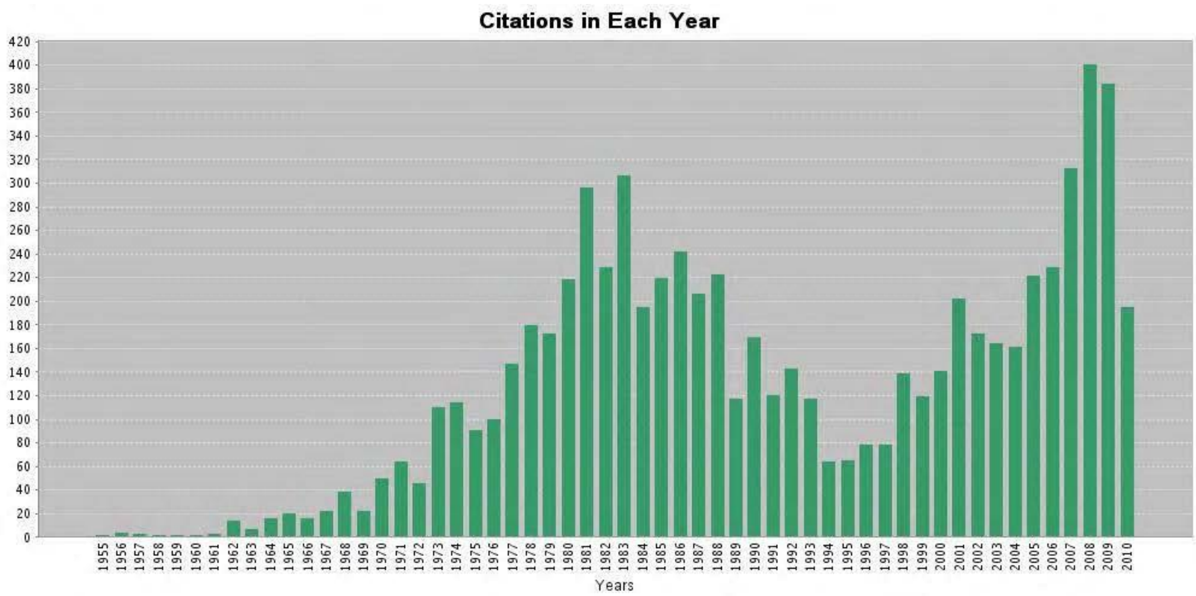
h-index: **35**

Last Updated: **05/08/2010 04:27 GMT**

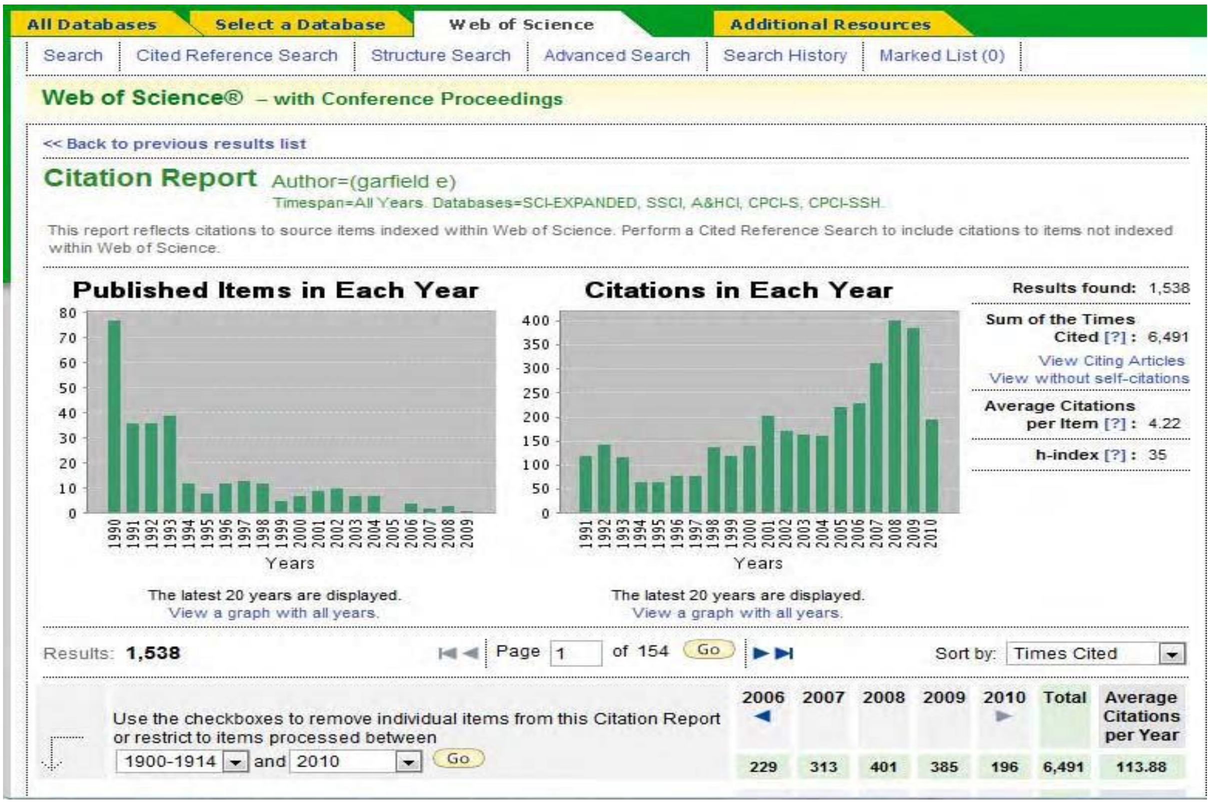
Excerpt from Garfield's Citation Report in WoS on June 13, 2010 The WoS Citation Report also shows (optionally) the citations to Garfield's work for his entire publishing time span as shown in the Figure



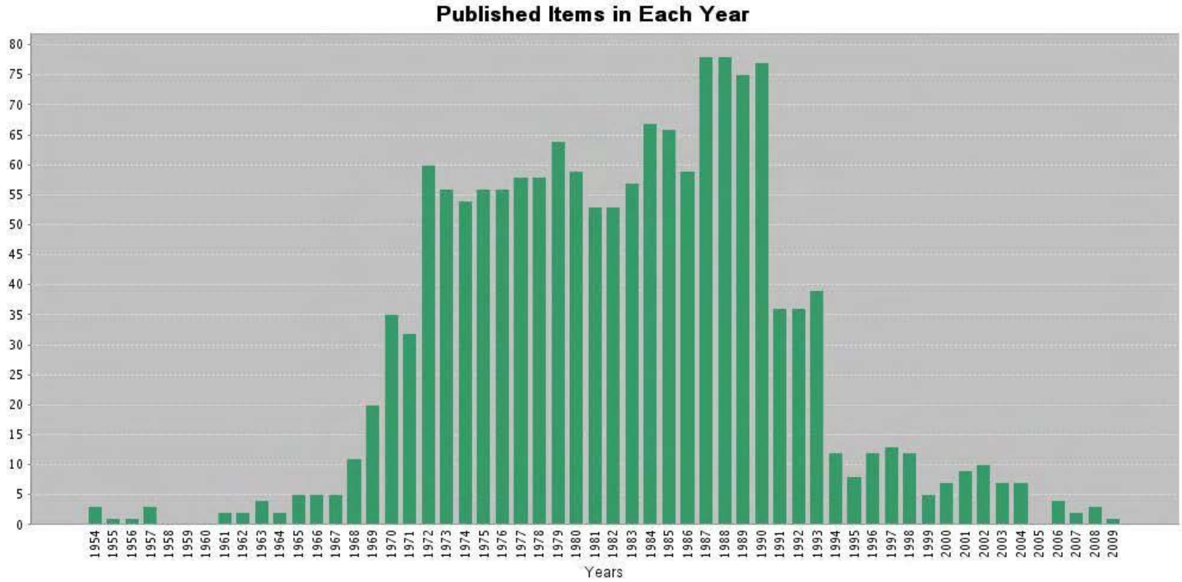
Citations received by Garfield since 1955



WoS Citation Report with key productivity and impact indicators



Master records for Garfield's publications in the WoS database



Excerpts from the list of journals where Garfield published

Source Titles Refine Exclude Cancel Sort these by: Record Count

The first 100 Source Titles (by record count) are shown. For advanced refine options, use Analyze results .

- CURRENT CONTENTS (1,066)
- SCIENTIST (146)
- CURRENT CONTENTS/LIFE SCIENCES (89)
- JOURNAL OF INFORMATION SCIENCE (13)
- JOURNAL OF CHEMICAL DOCUMENTATION (12)
- NATURE (12)
- JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE (11)
- ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY (10)
- SCIENCE (10)
- SCIENTOMETRICS (9)
- CURRENT COMMENTS (7)
- ANNALS OF INTERNAL MEDICINE (5)
- BRITISH MEDICAL JOURNAL (5)
- CURRENT SCIENCE (5)
- IEEE TRANSACTIONS ON PROFESSIONAL COMMUNICATION (5)
- JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION (5)
- JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY (5)
- CANADIAN MEDICAL ASSOCIATION JOURNAL (4)
- CHEMTECH (4)
- JOURNAL OF CHEMICAL INFORMATION AND COMPUTER SCIENCES (4)
- JOURNAL OF DOCUMENTATION (4)
- PROCEEDINGS OF THE ASIST ANNUAL MEETING (4)
- AMERICAN DOCUMENTATION (3)
- SPECIAL LIBRARIES (3)
- LIBRARY JOURNAL (2)
- LIBRARY QUARTERLY (2)
- NACHRICHTEN FUR DOKUMENTATION (2)
- NATURWISSENSCHAFTEN (2)
- AACE BULLETIN (1)
- ACS MISCELLANEOUS PUBLICATION (1)
- AMERICAN BEHAVIORAL SCIENTIST (1)
- AMERICAN SOCIOLOGIST (1)
- ANAESTHESIST (1)
- ANNALS OF BIOMEDICAL ENGINEERING (1)
- ANNALS OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE (1)
- ARBOR-CIENCIA PENSAMIENTO Y CULTURA (1)
- ARCHIVES OF PATHOLOGY (1)
- ARCHIVES OF SURGERY (1)
- ASIS MONOGRAPH SERIES (1)
- ASIST 2003: PROCEEDINGS OF THE 66TH ASIST ANNUAL MEETING, VOL 40, 2003 (1)
- ASIST 2004: PROCEEDINGS OF THE 67TH ASIS&T ANNUAL MEETING, VOL 41, 2004 (1)
- BIOLOGIYA MORYA-MARINE BIOLOGY (1)
- BIOSCIENCE (1)
- BULLETIN OF THE ATOMIC SCIENTISTS (1)
- BUSINESS SOFTWARE REVIEW (1)
- CANADIAN JOURNAL OF INFORMATION AND LIBRARY SCIENCE-REVUE CANADIENNE DES SCIENCES DE L INFORMATION ET DE BIBLIOTHECONOMIE (1)
- CANADIAN JOURNAL OF PSYCHIATRY-REVUE CANADIENNE DE PSYCHIATRIE (1)
- CANADIAN LIBRARY JOURNAL (1)
- FEMS MICROBIOLOGY LETTERS (1)
- FRONTIERS OF LIBRARIANSHIP-SYRACUSE UNIVERSITY (1)
- HEALTH INFORMATION AND LIBRARIES JOURNAL (1)
- INFORMATION SCIENTIST (1)
- INFORMATION TECHNOLOGY AND LIBRARIES (1)
- INNOVATION AT THE CROSSROADS BETWEEN SCIENCE AND TECHNOLOGY (1)
- INTERNATIONAL MICROBIOLOGY (1)
- ISRAEL JOURNAL OF AGRICULTURAL RESEARCH (1)
- JOURNAL OF CERAMIC PROCESSING RESEARCH (1)
- JOURNAL OF INFORMETRICS (1)
- JOURNAL OF NUCLEAR MEDICINE AND ALLIED SCIENCES (1)
- JOURNAL OF PUBLIC HEALTH DENTISTRY (1)
- JOURNAL OF THE AMERICAN CHEMICAL SOCIETY (1)
- JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION (1)
- JOURNAL OF THE HISTORY OF THE BEHAVIORAL SCIENCES (1)
- JOURNAL OF THE INDIAN INSTITUTE OF SCIENCE (1)
- JOURNAL OF THE OPTICAL SOCIETY OF AMERICA (1)
- JOURNAL OF THE PATENT OFFICE SOCIETY (1)
- LIBRI (1)
- MEDICAL JOURNAL OF AUSTRALIA (1)
- METHODS OF INFORMATION IN MEDICINE (1)
- NEW ENGLAND JOURNAL OF MEDICINE (1)
- NEW SCIENTIST (1)
- OCCUPATIONAL MEDICINE-OXFORD (1)

Subject areas of journals that published Garfield's papers

View Distinct Author Sets for garfield e

The Distinct Author Set feature is a discovery tool showing sets of papers likely written by the same person. (Tell me more.)

Results: **1,538**

Sort by: Latest Date

Subject Areas Refine Exclude Cancel Sort these by: Record Count

The first 100 Subject Areas (by record count) are shown. For advanced refine options, use Analyze results .

MULTIDISCIPLINARY SCIENCES (1,343)	LAW (2)	INTERNATIONAL RELATIONS (1)
SOCIAL SCIENCES, INTERDISCIPLINARY (1,159)	MICROBIOLOGY (2)	MARINE & FRESHWATER BIOLOGY (1)
INFORMATION SCIENCE & LIBRARY SCIENCE (219)	PSYCHOLOGY (2)	MATERIALS SCIENCE, CERAMICS (1)
COMPUTER SCIENCE, INFORMATION SYSTEMS (53)	AGRICULTURE, MULTIDISCIPLINARY (1)	MEDICAL INFORMATICS (1)
MEDICINE, GENERAL & INTERNAL (28)	ANESTHESIOLOGY (1)	MEDICINE, LEGAL (1)
COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS (25)	ANTHROPOLOGY (1)	NEUROSCIENCES (1)
CHEMISTRY, MULTIDISCIPLINARY (20)	AUTOMATION & CONTROL SYSTEMS (1)	PATHOLOGY (1)
ENGINEERING, MULTIDISCIPLINARY (6)	BEHAVIORAL SCIENCES (1)	PEDIATRICS (1)
BIOCHEMISTRY & MOLECULAR BIOLOGY (5)	BIOTECHNOLOGY & APPLIED MICROBIOLOGY (1)	PHILOSOPHY (1)
CHEMISTRY, APPLIED (5)	BUSINESS (1)	PHYSICS, MULTIDISCIPLINARY (1)
COMMUNICATION (5)	COMPUTER SCIENCE, SOFTWARE ENGINEERING (1)	POLITICAL SCIENCE (1)
ENGINEERING, CHEMICAL (4)	DENTISTRY, ORAL SURGERY & MEDICINE (1)	PSYCHIATRY (1)
PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH (4)	EDUCATION, SCIENTIFIC DISCIPLINES (1)	PSYCHOLOGY, CLINICAL (1)
SOCIAL ISSUES (3)	EMERGENCY MEDICINE (1)	PSYCHOLOGY, MULTIDISCIPLINARY (1)
SURGERY (3)	ENGINEERING, BIOMEDICAL (1)	RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING (1)
BIOLOGY (2)	ENGINEERING, MECHANICAL (1)	SOCIOLOGY (1)
CELL BIOLOGY (2)	HEALTH CARE SCIENCES & SERVICES (1)	STATISTICS & PROBABILITY (1)
FOOD SCIENCE & TECHNOLOGY (2)	HISTORY (1)	TOXICOLOGY (1)
HISTORY & PHILOSOPHY OF SCIENCE (2)	HUMANITIES, MULTIDISCIPLINARY (1)	VETERINARY SCIENCES (1)
HISTORY OF SOCIAL SCIENCES (2)	INSTRUMENTS & INSTRUMENTATION (1)	

Distribution of papers citing Garfield by language

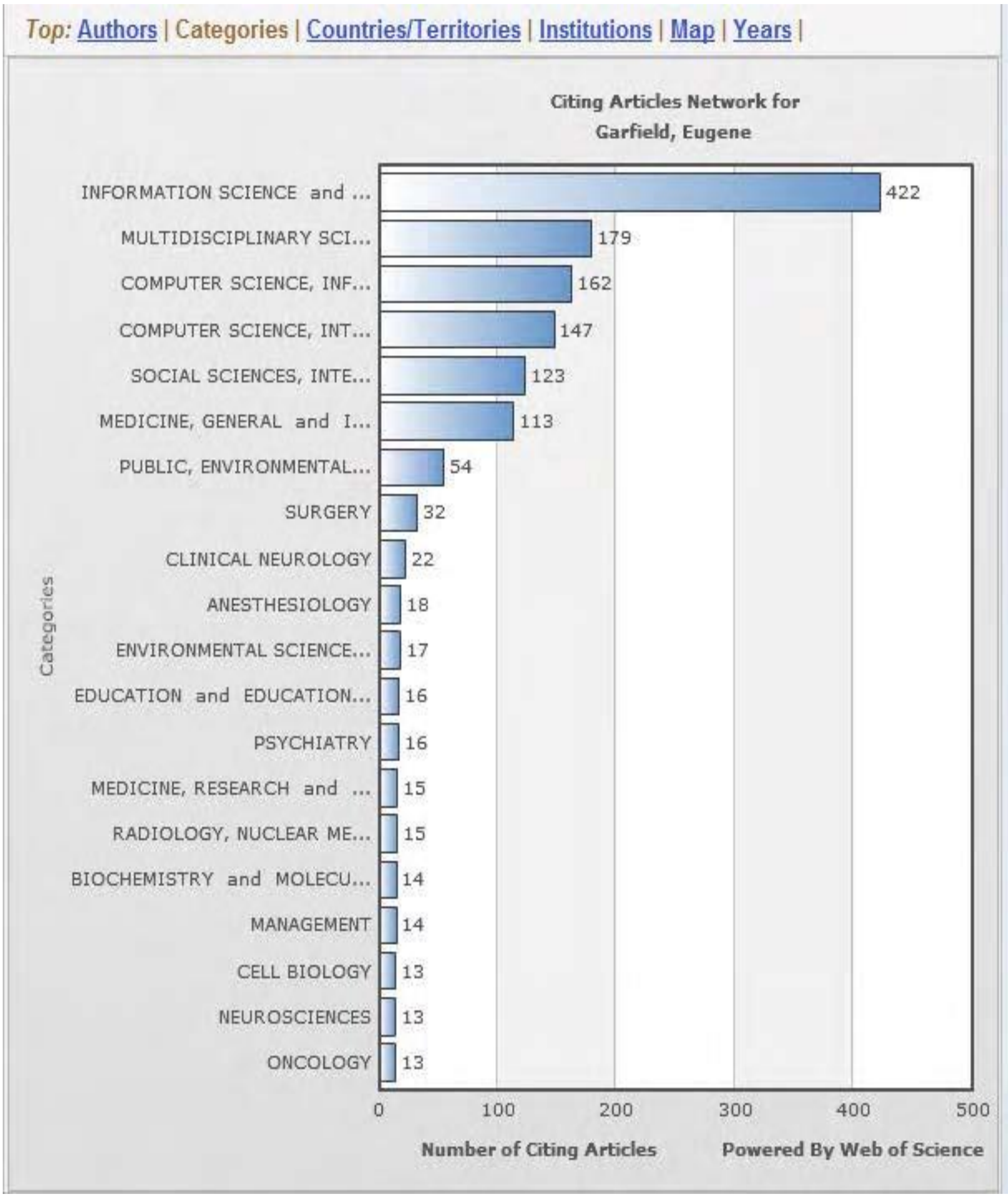
Languages Refine Exclude Cancel Sort these by: Record

The first 100 Languages (by record count) are shown. For advanced refine options, use

ENGLISH (2,830)	JAPANESE (20)	ITALIAN (3)	SERBIAN (1)
SPANISH (81)	CZECH (13)	SERBO-CROATIAN (3)	SLOVENE (1)
GERMAN (68)	PORTUGUESE (9)	CROATIAN (2)	SWEDISH (1)
FRENCH (40)	HUNGARIAN (3)	LITHUANIAN (2)	UKRAINIAN (1)
RUSSIAN (35)			

Refine Exclude Cancel Sort these by: Record Count

Citations received by subject category according to ResearchID



Periodicals that most often cite the works of Garfield

Results: 3,113

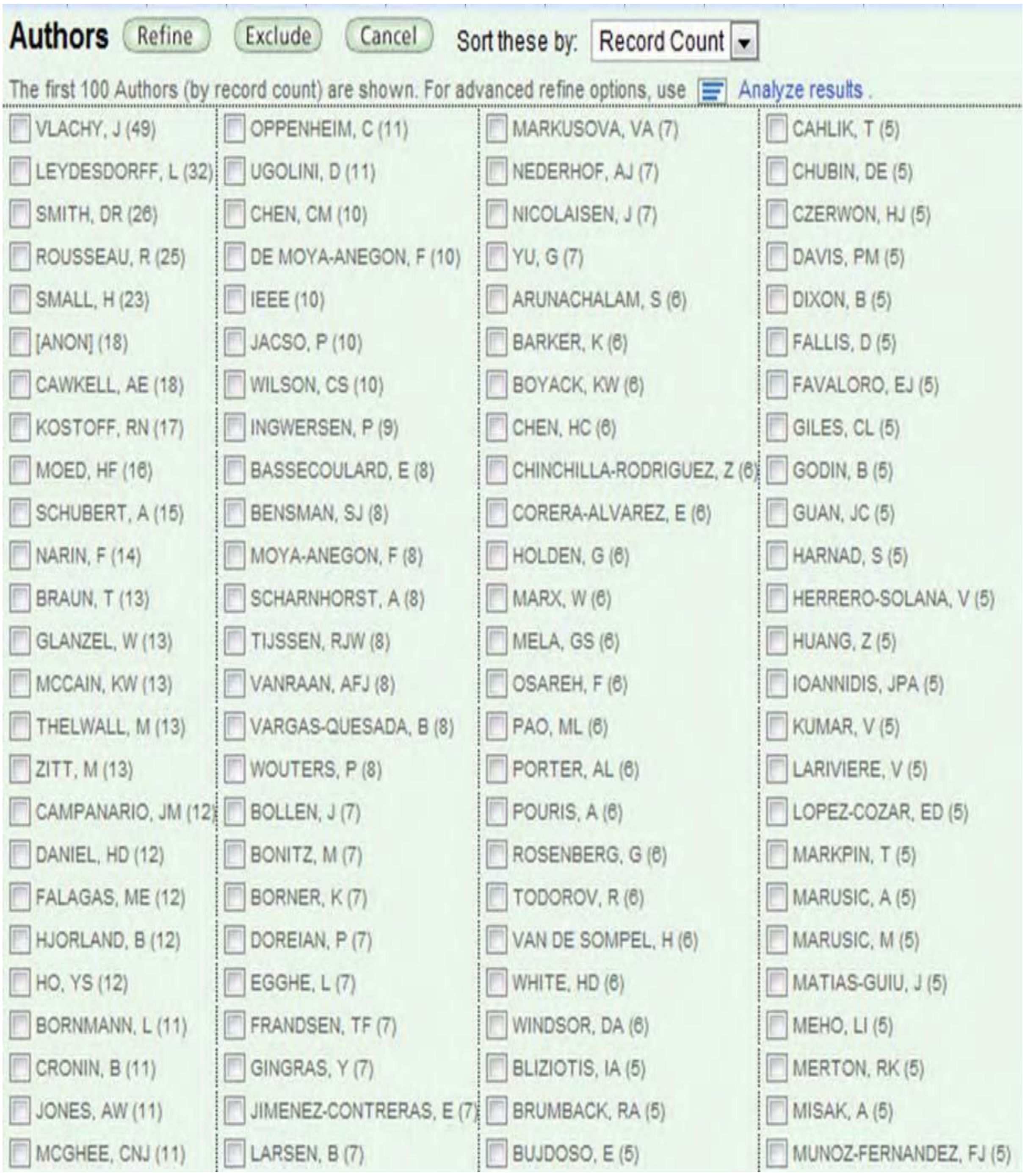
Sort by: Times Cited

Source Titles Refine Exclude Cancel Sort these by: Record Count

The first 100 Source Titles (by record count) are shown. For advanced refine options, use Analyze results .

- SCIENTOMETRICS (326)
- JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY (100)
- JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE (80)
- JOURNAL OF DOCUMENTATION (58)
- CZECHOSLOVAK JOURNAL OF PHYSICS (50)
- JOURNAL OF INFORMATION SCIENCE (40)
- ANNUAL REVIEW OF INFORMATION SCIENCE AND TECHNOLOGY (39)
- SCIENTIST (38)
- JOURNAL OF CHEMICAL DOCUMENTATION (29)
- JOURNAL OF INFORMETRICS (27)
- BULLETIN OF THE MEDICAL LIBRARY ASSOCIATION (26)
- INFORMATION PROCESSING & MANAGEMENT (24)
- JOURNAL OF CHEMICAL INFORMATION AND COMPUTER SCIENCES (24)
- ASIST MONOGRAPH SERIES (23)
- NAUCHNO-TEKHNICHESKAYA INFORMATSIYA SERIYA 1-ORGANIZATSIYA I METODIKA INFORMATSIONNOI RABOTY (21)
- PROCEEDINGS OF ISSI 2007: 11TH INTERNATIONAL CONFERENCE OF THE INTERNATIONAL SOCIETY FOR SCIENTOMETRICS AND INFORMETRICS, VOLS I AND II (20)
- COLLEGE & RESEARCH LIBRARIES (19)
- LIBRARY TRENDS (19)
- CURRENT SCIENCE (18)
- AMERICAN PSYCHOLOGIST (17)
- LIBRARY AND INFORMATION SCIENCE (17)
- SPECIAL LIBRARIES (13)
- LIBRARY & INFORMATION SCIENCE RESEARCH (12)
- LIBRARY QUARTERLY (12)
- LIBRI (12)
- WEB OF KNOWLEDGE - A FESTSCHRIFT IN HONOR OF EUGENE GARFIELD (12)
- LIBRARY RESOURCES & TECHNICAL SERVICES (11)
- SCIENCE (11)
- 8TH INTERNATIONAL CONFERENCE ON SCIENTOMETRICS AND INFORMETRICS, VOLS 1 AND 2 - ISSI-2001, PROCEEDINGS (10)
- AMERICAN DOCUMENTATION (10)
- SOCIAL STUDIES OF SCIENCE (10)
- CURRENT CONTENTS/LIFE SCIENCES (9)
- LEARNED PUBLISHING (9)
- NACHRICHTEN FUR DOKUMENTATION (9)
- ONLINE INFORMATION REVIEW (9)
- PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON SCIENTOMETRICS AND INFORMETRICS (9)
- ARCHIVUM IMMUNOLOGIAE ET THERAPIAE EXPERIMENTALIS (8)
- CANADIAN MEDICAL ASSOCIATION JOURNAL (8)
- NAUCHNO-TEKHNICHESKAYA INFORMATSIYA SERIYA 2-INFORMATSIONNYE PROTSESSY I SISTEMY (8)
- SCHOLARLY PUBLISHING (8)
- CLINICAL AND EXPERIMENTAL OPHTHALMOLOGY (7)
- CORTEX (7)
- CHEMICKE LISTY (6)
- CURRENT CONTENTS/PHYSICAL CHEMICAL & EARTH SCIENCES (6)
- DEUTSCHE MEDIZINISCHE WOCHENSCHRIFT (6)
- IEEE TRANSACTIONS ON PROFESSIONAL COMMUNICATION (6)
- INDUSTRIAL HEALTH (6)
- JOURNAL OF ACADEMIC LIBRARIANSHIP (6)
- JOURNAL OF CHILD NEUROLOGY (6)
- JOURNAL OF CLINICAL EPIDEMIOLOGY (6)
- JOURNAL OF NANOPARTICLE RESEARCH (6)
- KNOWLEDGE ORGANIZATION (6)
- PLASTIC AND RECONSTRUCTIVE SURGERY (6)
- PROFESIONAL DE LA INFORMACION (6)
- SCIENCE AND ENGINEERING ETHICS (6)
- SOUTH AFRICAN JOURNAL OF SCIENCE (6)
- WIENER KLINISCHE WOCHENSCHRIFT (6)
- ANNALS OF EMERGENCY MEDICINE (5)
- ASIS MONOGRAPH SERIES (5)
- AUSTRALIAN AND NEW ZEALAND JOURNAL OF PSYCHIATRY (5)
- BULLETIN OF THE BRITISH PSYCHOLOGICAL SOCIETY (5)
- CHEMISTRY IN BRITAIN (5)
- CURRENT CONTENTS/SOCIAL & BEHAVIORAL SCIENCES

<u>Teaching and research faculty members most often citing Garfield</u>



Authors Refine Exclude Cancel Sort these by: Record Count

The first 100 Authors (by record count) are shown. For advanced refine options, use Analyze results .

VLACHY, J (49)	OPPENHEIM, C (11)	MARKUSOVA, VA (7)	CAHLIK, T (5)
LEYDESDORFF, L (32)	UGOLINI, D (11)	NEDERHOF, AJ (7)	CHUBIN, DE (5)
SMITH, DR (26)	CHEN, CM (10)	NICOLAISEN, J (7)	CZERWON, HJ (5)
ROUSSEAU, R (25)	DE MOYA-ANEGON, F (10)	YU, G (7)	DAVIS, PM (5)
SMALL, H (23)	IEEE (10)	ARUNACHALAM, S (6)	DIXON, B (5)
[ANON] (18)	JACSO, P (10)	BARKER, K (6)	FALLIS, D (5)
CAWKELL, AE (18)	WILSON, CS (10)	BOYACK, KW (6)	FAVALORO, EJ (5)
KOSTOFF, RN (17)	INGWERSEN, P (9)	CHEN, HC (6)	GILES, CL (5)
MOED, HF (16)	BASSECOULARD, E (8)	CHINCHILLA-RODRIGUEZ, Z (6)	GODIN, B (5)
SCHUBERT, A (15)	BENSMAN, SJ (8)	CORERA-ALVAREZ, E (6)	GUAN, JC (5)
NARIN, F (14)	MOYA-ANEGON, F (8)	HOLDEN, G (6)	HARNAD, S (5)
BRAUN, T (13)	SCHARNHORST, A (8)	MARX, W (6)	HERRERO-SOLANA, V (5)
GLANZEL, W (13)	TIJSSEN, RJW (8)	MELA, GS (6)	HUANG, Z (5)
MCCAIN, KW (13)	VANRAAN, AFJ (8)	OSAREH, F (6)	IOANNIDIS, JPA (5)
THELWALL, M (13)	VARGAS-QUESADA, B (8)	PAO, ML (6)	KUMAR, V (5)
ZITT, M (13)	WOUTERS, P (8)	PORTER, AL (6)	LARIVIERE, V (5)
CAMPANARIO, JM (12	BOLLEN, J (7)	POURIS, A (6)	LOPEZ-COZAR, ED (5)
DANIEL, HD (12)	BONITZ, M (7)	ROSENBERG, G (6)	MARKPIN, T (5)
FALAGAS, ME (12)	BORNER, K (7)	TODOROV, R (6)	MARUSIC, A (5)
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HO, YS (12)	EGGHE, L (7)	WHITE, HD (6)	MATIAS-GUIU, J (5)
BORNMANN, L (11)	FRANDSEN, TF (7)	WINDSOR, DA (6)	MEHO, LI (5)
CRONIN, B (11)	GINGRAS, Y (7)	BLIZIOTIS, IA (5)	MERTON, RK (5)
JONES, AW (11)	JIMENEZ-CONTRERAS, E (7	BRUMBACK, RA (5)	MISAK, A (5)
MCGHEE, CNJ (11)	LARSEN, B (7)	BUJDOSO, E (5)	MUNOZ-FERNANDEZ, FJ (5)

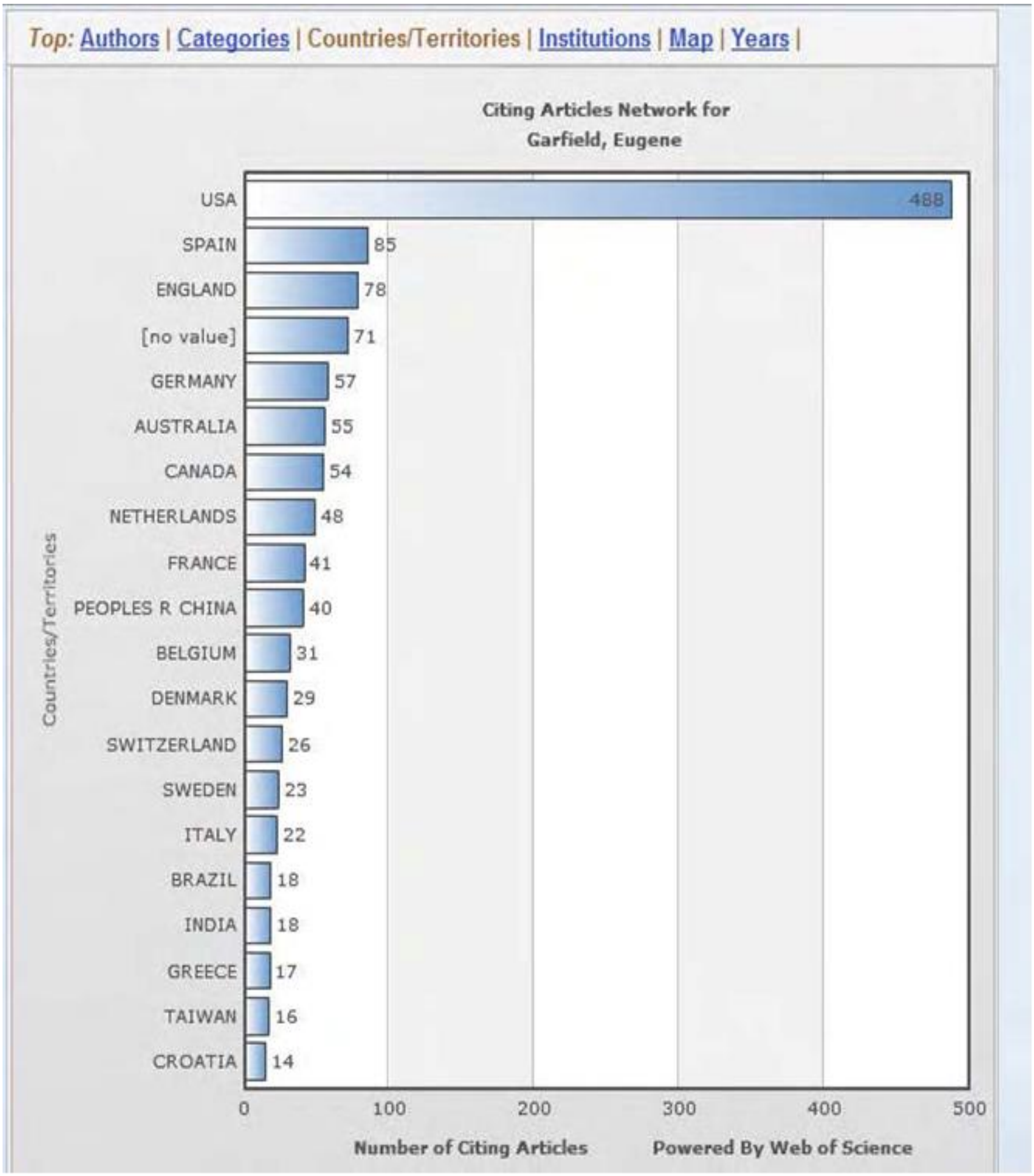
Institutions citing Garfield's paper the most often

Institutions Refine Exclude Cancel Sort these by: Record Count

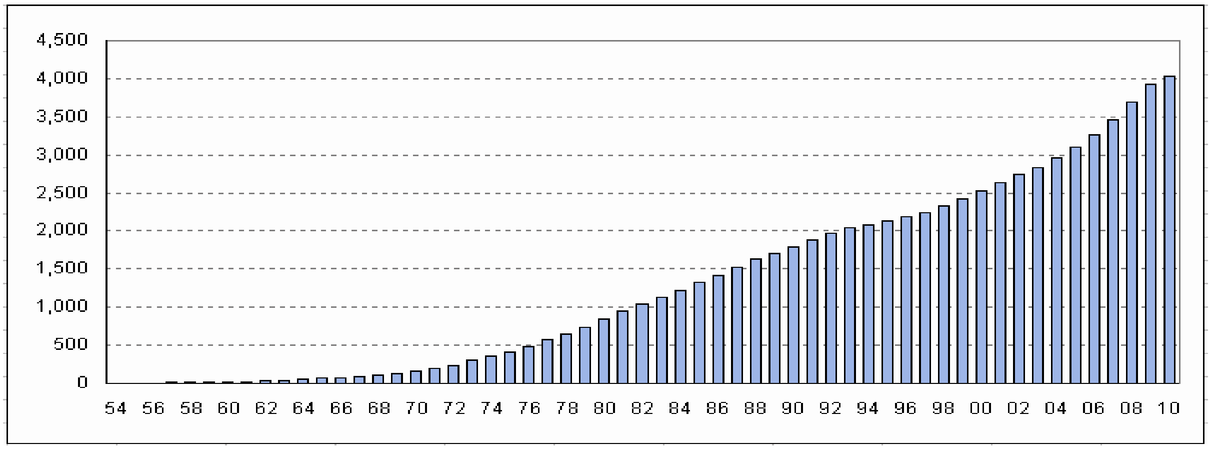
The first 100 Institutions (by record count) are shown. For advanced refine options, use Analyze results .

INDIANA UNIV (48)	UNIV ALCALA DE HENARES (14)	SWISS FED INST TECHNOL (9)
ROYAL SCH LIB & INFORMAT SCI (39)	UNIV MARYLAND (14)	TEXAS A&M UNIV (9)
UNIV GRANADA (36)	UNIV MINNESOTA (14)	UNIV EXTREMADURA (9)
DREXEL UNIV (33)	UNIV WASHINGTON (14)	UNIV LEICESTER (9)
INST SCI INFORMAT (30)	UNIV AUCKLAND (13)	UNIV LEIDEN (9)
LEIDEN UNIV (27)	UNIV FLORIDA (13)	UNIV MELBOURNE (9)
HUNGARIAN ACAD SCI (24)	UNIV N CAROLINA (13)	UNIV NACL AUTONOMA MEXICO (9)
UNIV MICHIGAN (24)	UNIV PITTSBURGH (13)	CREIGHTON UNIV (8)
UNIV AMSTERDAM (23)	INRA (12)	HUMBOLDT UNIV (8)
UNIV PENN (22)	UNIV KENTUCKY (12)	L EOTVOS UNIV (8)
CORNELL UNIV (21)	UNIV QUEBEC (12)	LINKOPING UNIV HOSP (8)
UNIV ILLINOIS (20)	UNIV SHEFFIELD (12)	MCGILL UNIV (8)
UNIV NEWCASTLE (20)	UNIV SYDNEY (12)	MCMASTER UNIV (8)
UNIV TORONTO (20)	VIRGINIA POLYTECH INST & STATE UNIV (12)	NYU (8)
HARVARD UNIV (19)	WOLVERHAMPTON UNIV (12)	SUNY BUFFALO (8)
TUFTS UNIV (18)	INST SCI INFORMATION (11)	UNIV AUTONOMA BARCELONA (8)
UNIV CALIF LOS ANGELES (18)	JOHNS HOPKINS UNIV (11)	UNIV HAWAII (8)
UNIV GENOA (18)	KHBO (11)	UNIV INSTELLING ANTWERP (8)
UNIV WESTERN ONTARIO (18)	LOS ALAMOS NATL LAB (11)	UNIV MANCHESTER (8)
CSIC (17)	UNIV CALIF SAN FRANCISCO (11)	UNIV MONTREAL (8)
LOUISIANA STATE UNIV (17)	ARIZONA STATE UNIV (10)	UNIV OKLAHOMA (8)
OFF NAVAL RES (17)	ETH (10)	BULGARIAN ACAD SCI (7)
PENN STATE UNIV (17)	HEBREW UNIV JERUSALEM (10)	CHARLES UNIV (7)
UNIV ARIZONA (17)	UNIV CALIF BERKELEY (10)	FLORIDA STATE UNIV (7)
UNIV BRITISH COLUMBIA (17)	UNIV CAMBRIDGE (10)	HARBIN INST TECHNOL (7)
UNIV TEXAS (17)	UNIV ZURICH (10)	PURDUE UNIV (7)
COLUMBIA UNIV (16)	ALFA INST BIOMED SCI (9)	ROUEN UNIV HOSP (7)

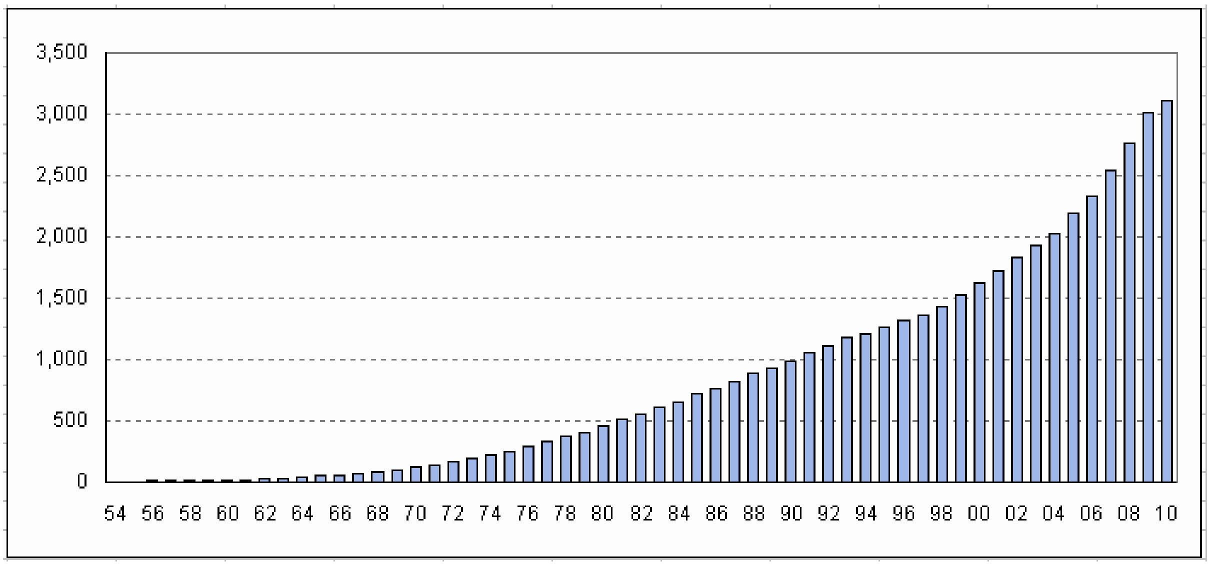
Distribution of citations received by Garfield by country according to ResearcherID



Cumulative number of publications citing Garfield's publications



Cumulative number of publications citing Garfield's publications - without self citation



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'*THE IMPACT OF EUGENE GARFIELD THROUGH THE PRISM OF WEB OF SCIENCE*'

Peter Jacso
Professor, Department of Information and Computer Sciences,
University of Hawai'i at Mãnoa, Honolulu
Email: jacso@hawaii.edu
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Tributes

to

Prof Dr Eugene Garfield

[A] Proceedings of the Association for Information Science and Technology

This panel pays tribute to Dr. Eugene Garfield, one of the "fathers" of bibliometrics, former president of ASIS (1999–2000) and the founder of the ISI citation databases. Dr. Garfield passed away on February 25, 2017. In this panel, we will highlight his contributions to information science. The panelists are all well-known researchers who have known and worked with r. Garfield. Each panelist will highlight an aspect of Dr. Garfield's contributions that has transformed science and scholarship and how, in turn, their own work has been influenced by his contributions. The panel will be moderated by Judit Bar-Ilan and Dietmar Wolfram.

[B] Alan Wayne Jones PhD DSc

University of Linkoping, Sweden

Eugene Garfield PhD was a pioneer in the field of scientific information, documentation and especially the use of citation analysisto evaluate the importance of scholarly articles. Early in his career Gene Garfield realized that scrutinizing the list of referencesin a scientific article could furnish a wealth of information linking the provenance of current research to previously publishedwork. The more citations an article gets the more useful it must have been for later advances in that particular scientific fieldor discipline. Citation metrics are now widely used in academia to compare and contrast scholarly articles and the oeuvre ofa research scientist or an entire university department. In the 1960s Garfield founded the Institute for Scientific Information(ISI), which later became Thomson Reuters ISI and more recently Clarivate Analytics. Among many innovative products fortracking and documenting developments in science, ISI produced Current Contents, Science Citation Index, Journal CitationReports, ScienceWatch, and InCites. Many of these bibliometric tools are incorporated into the Web-of-Science database, whichrepresents the most comprehensive source of information about cited authors and cited papers. Gene Garfield had a globalinfluence on many scientists and he sparked my own interests in the field of bibliometrics, informetrics and/or scientometrics.With the

passing of Gene Garfield, the world of scientific information has lost a remarkably innovative and charming person.

[C] Journal of Informatrics

Obituary

A tribute to Eugene Garfield: Information innovator and idealist

Henry Small
SciTech Strategies, Inc., 105 Rolling Road, Bala Cynwyd, PA 19004, USA

No other individual has had a greater influence on the fields of scientometrics, informetrics, and information science generally than Eugene Garfield. Most of his contributions over the decades are found to have had their origins very early in his career. Chemistry and chemical information launched his career and led to his involvement with medical information, computing technology, and the field of documentation. Content page products provided the foundation to his business, and the singular invention of a citation index for science, his most far-reaching achievement, led to many spin offs including journal analyses, historical charting, evaluation, and science mapping. His idea for a science newspaper was derived from his early work in current awareness. The paper concludes with discussion of his management style, approach to business and philanthropy, and how they shed light on his complex personality and motivations.

[A Full Article is enclosed]

[D] Scientometrics

A tribute to Eugene Garfield: Discovering the intellectual base of his discipline.

[A Full Article is enclosed]

Journal of Informetrics 11 (2017) 599–612

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journal homepage: www.elsevier.com/locate/joi

Obituary

A tribute to Eugene Garfield: Information innovator and idealist

ARTICLE INFO

ABSTRACT

No other individual has had a greater influence on the fields of scientometrics, informetrics, and information science generally than Eugene Garfield. Most of his contributions over the decades are found to have had their origins very early in his career. Chemistry and chemical information launched his career and led to his involvement with medical information, computing technology, and the field of documentation. Content page products provided the foundation to his business, and the singular invention of a citation index for science, his most far reaching achievement, led to many spin offs including journal analyses, historical charting, evaluation, and science mapping. His idea for a science newspaper was derived from his early work in current awareness. The paper concludes with discussion of his management style, approach to business and philanthropy, and how they shed light on his complex personality and motivations.

1. Introduction

With the passing of Gene Garfield at the age of 91 years on February 26, 2017, we have lost one of the great pioneers and innovators of the information age. It was my good fortune to have been associated with Gene for 45 years. It was exciting to be involved in the applications of citation indexing, and it continues to be an intellectually rewarding journey. I think this is because the database he created is an incredible window onto the entire scientific landscape

For me Gene was a larger-than-life figure who was a commanding presence in my working life at the Institute for Scientific Information (ISI), the company he founded. He was in turn an information pioneer, innovator, entrepreneur, a demanding boss, outspoken critic, a fighter for what he believed in, a nudge, a workaholic, a mentor, a father figure, good friend, and generous soul. Clearly, this is a complex picture and most people who have worked with him feel many conflicting emotions. But without his dogged and sometimes annoying persistence, it is unlikely that we would have seen the products, services, and ideas that have been for me and scholars the world over the essential nutrients of our intellectual life. Through his contributions many of us have built our careers

When I went to work at ISI in 1972, I did not realize that I would witness the birth of a new field of scholarship we call scientometrics and informetrics. The development of the new field was made possible in large part by Gene's citation index in combination with the rapidly expanding power of computing

We are fortunate to have many excellent accounts of his life in the form of audio and video interviews and historical accounts written by him or by colleagues (Garfield, 1987; Garfield, 1997, 2007; Thackray & Brock, 2000; Wouters, 1999). What I will do here is highlight some his achievements and how they were an expression of his unique personality, ambition, and idealism

2. Chemical indexing products

We now think of Gene mainly in terms of his most successful and visible products, namely *Current Contents* and the *Science Citation Index*. But his early work was in chemistry and chemical indexing. He studied chemical engineering for one semester at the University of Colorado before joining the army, and after the army continued his schooling at Columbia University. In 1949 he graduated with a degree in chemistry but could not find a job as a chemist. With a recommendation from a cousin who was working on his PhD at Columbia, he got a job in the lab of the prominent chemist, Louis P. Hammett

http://dx.doi.org/10.1016/j.joi.2017.04.006
1751-1577/

His interest in chemical information stems from his work in Hammett's lab. Gene learned how to do literature searches in Chemical Abstracts and also created an index for the chemicals in Hammett's store room which had been synthesized in the lab. He had learned typing in a high school summer course and thought at one point that he might be a secretary. It turned out that this skill was very useful in his indexing work. However, due to some mishaps and explosions in Hammett's lab, he was fired. "I think it might be a good idea if you modify your career expectations" Hammett told him diplomatically (Garfield, 2007, 17)

Gene often said that one reason for his success was his ability to talk to anyone. Attending a meeting of the American Chemical Society in New York, he introduced himself to James W. Perry, a chemical engineer, who had given a presentation on chemical information sponsored by the ACS Division of Chemical Literature. Gene asked him "How do you get a job in this racket?", and invited Perry to dinner at his mother's home. Perry offered him a job at MIT, but before that could happen, the project lost funding. At Perry's suggestion, he went to Johns Hopkins in Baltimore but discovered that his job would be with Sanford Larkey at the Welch Medical Library working on chemical nomenclature. It turned out that Larkey was a friend of Perry. Later on, gaining access to his personnel file at the Welch Medical Library, Gene found out that Hammett, whom he had given as a reference, had written a letter to Larkey stating that "Garfield is an extremely hard worker but not a particularly original thinker." Looking back with a smile Gene would later say, "Was he surprised!" (Garfield, 2007, 18)

His work in chemical information continued in 1954, after he had completed a library degree at Columbia. At that time he relocated to Philadelphia and took a job as a consultant at the drug company SmithKline & French where one of his projects was indexing steroids. These were identified by scanning journal articles. Realizing that Chemical Abstracts was seriously out of date, he came up with the idea for a chemical information service that would quickly identify newly synthesized chemical compounds. This became his first chemical product in 1960 which he called Index Chemicus. Like his steroid work, this was based on a scanning of journal articles. Needing a way to identify and index new compounds, he developed a method for converting chemical names into molecular formulas which could be easily indexed. This conversion method became the basis of his PhD from the linguistics department of the University of Pennsylvania which at 10 pages became, somewhat notoriously, the shortest PhD dissertation ever granted by the department

3. Contents page services

In some ways, the foundation of Gene's career was the idea of providing the table of contents pages of journals in a timely manner which served the needs of readers to find out the latest publications in their field and of publishers to publicize their

Fig. 1. Gene Garfield in the 1950 with an early version of Current Contents.

upcoming content. In fact, *Current Contents* was the first, best known, and most commercially successful of his products, and for many years provided a critical source of revenue for his other ventures (Fig. 1).

One event in his early life remarkably foreshadows his later interest in title scanning. As a young boy his apartment in the Bronx was across the street from a branch of the New York Public Library. He recalls going into the adult section of the library and reading the titles of books on the shelves until he could see them in his head. Late in life he could still recall some of the titles. Was this a refuge from adversity, simple curiosity, or bragging rights? He could not say.

His first job in the field of information was, as mentioned, working at the Welch Medical Library at Johns Hopkins in Baltimore. The Welch project was sponsored by the Army Medical Library and was the precursor of the National Library of Medicine where, among other things, pioneering work was done on what would later become Index Medicus, and the Medical Subject Heading (Mesh) system. At the project he got to meet many of the leading librarians of the day. Part of his job was to work on the Current List of Medical Literature, a publication of titles of medical articles indexed by the project. On his own and without the approval from the project's director, Larkey, Gene decided to produce a similar service for library and information science journals which he called "Contents in Advance". To compile it, he wrote to journal publishers to obtain the contents pages of their forthcoming issues which he reproduced photographically. He had realized in his work on the Current List and also with Chemical Abstracts that indexing services were very slow due to the amount of indexing work required to produce them. His solution was to create a product that would alert readers to new articles as soon as they were available from publishers. This emphasis on timeliness became one of his mantras and affected every other product he produced.

Larkey, however, did not approve of Contents in Advance, even if Gene was doing it on his own time, and his refusal to stop work on it led to his being fired from the Welch project. However, the publication continued after he left the project and went to Columbia Library School. Later on, after relocating to Philadelphia, he undertook other specialized contents page products for management and pharmaceutical journals which eventually morphed into the various editions of *Current Contents* (CC).

4. Punch cards and computers

The advent of computers and punch card technology for storing and searching data had opened up new horizons for libraries and information centers. Gene got his first exposure to this technology on the Welch project. There he gained his reputation as an IBM punch card "guru" and information "engineer", as he called himself, and an expert at programming the IBM 101 statistical machine which had newly arrived in a building across the street from the library. This involved programming the IBM 101 by the method of rewiring which he learned from reading manuals and talking to IBM representatives. He was able to program the machine to search simultaneously on multiple classification codes of medical articles through the method of superimposed coding which had been developed by Calvin Mooers. One of Gene's earliest published papers in 1954 dealt with the use of punch card technology (Garfield, 1954).

He had a talent for seeing how what we would now consider to be primitive computer technology could be applied to solve large scale information problems. This was particularly true in his proposal for a citation index for science. In effect, he was able to find an engineering solution to an information problem, using punch card technology to store and manipulate the data records.

After leaving the Welch project and completing his library degree, he wanted to pursue a PhD and tried to put together an interdisciplinary committee since Columbia did not have a PhD program in library science. The title of his proposal was "Machine Methods of Scientific Documentation: the Application of Computers". However, he was thwarted in his efforts when it proved impossible to convene the committee. He initially set up his business in Philadelphia first calling it "DocuMation Inc.", later changing it to "Eugene Garfield Associates – Information Engineers". However, he was informed by the State of Pennsylvania that he could not call himself an engineer because he had not been licensed.

5. Citation index for science – conception

The origin of the idea for a citation index for science holds particular fascination because, of all of Gene's innovations, it has had the greatest impact, not only on information retrieval, but also on the field of scientometrics. In the 1950s the idea of creating a unified index for all of science was gaining momentum, including a possible role for the Federal government in building a national documentation center for science (Garfield & Hayne, 1955). Early ideas included combining of information from all the then available disciplinary services into one giant enterprise. Centralization and government support seemed important not only because of the magnitude of the task but also the need for cross-disciplinary research.

The head of the advisory committee at the Welch project, Chauncey Leake, had been pestering Gene to study review articles and find out why they were so important to scientists. He studied reviews and realized that almost every sentence was like an indexing statement associated with a bibliographic reference, like "a continuous string of indexing statements" (Thackray & Brock, 2000). His first thought was that perhaps these statements could be used somehow in his indexing work on the Welch project and he wrote a paper on the idea (Garfield, 1952, 1963). Thus, Leake's suggestion had focused Gene's attention on references in scientific papers.

The next piece of the puzzle came from an unexpected place, via a letter from William Adair, the retired president of Shepard's, a citation index to legal decisions (Wouters, 1999, 23). Adair's letter had been prompted by a conference held at

Fig. 2. Gene Garfield (second from left) at the Symposium on machine methods in scientific documentation in 1953.

the Welch Library which Gene had played a major role in organizing. The opening speaker was Lowell Reed, a vice president of Johns Hopkins, whose statement that "man was going to drown in a flood of papers" was picked up by the newspaper wire services and came to Adair's attention in Colorado (Fig. 2).

The letter from Adair suggested that the legal citator idea used in Shepard's might be applicable to science, and that indeed he had suggested that it be used to index the medical and engineering literature back in the 1930s. Shepard's enabled lawyers to look up an older court decision and see whether more recent cases had affirmed or overturned the original one. Since Gene had never seen Shepard's, he went over to the Enoch Pratt Central Library in Baltimore to have a look. Putting the citator idea together with his insight into how review articles index references, the lightbulb went off.

While at Columbia for his library degree, he wrote a term paper on citation indexing which became the basis of his landmark 1955 paper in Science (Garfield, 1955). In his new role as an associate editor of American Documentation, he also asked Adair to write a paper on how the citator idea could be applied to scientific literature (Adair, 1955).

Gene's 1955 Science paper described how a citation index could be constructed from elemental building blocks of citing and cited records that could be numerically coded to fit into the 80 columns of an IBM punch card. The index also required an inversion of the order of references from how they are presented in the literature to their arrangement by cited item, so that a user could look up a reference and find where it had been cited, turning the usual order of presentation on its head.

The paper stressed the value of a citation index for information retrieval, especially in bringing to light criticisms of earlier papers, to prevent the propagation of "uncritical citation of fraudulent, incomplete or obsolete data". On a more positive note, he went on to say that a citation represents an association of ideas between citing and cited authors, and that this association is at the "molecular" unit of thought, rather than the more general subject category level of traditional indexes. But, he asserted, the citation index could also be used in historical research to assess the "impact" or "significance" of a work for its historical period, including the transmission of ideas, and would enable historians to "measure the influence of the article – that is its 'impact factor"'. In short, he saw the value of citation indexing both in terms of retrieval of highly targeted information and for assessing impact, a dual purpose that set the framework for much of the work to follow.

Fig. 3. From left, Hilary Koprowski, Gene Garfield, and Joshua Lederberg at an ISI Board of Directors meeting.

6. Science Citation Index – birth

Initial efforts to obtain government funding to create a citation index, however, were not successful, in part, because Gene was not affiliated with an academic institution. He also attempted to sell the U.S. Patent Office on the idea of a citation index for patents. The National Science Foundation had also turned down his proposal, but he did get support from Gordon Allen, a geneticist at the NIH. Wouters has described all the twists and turns in getting the citation index off the ground (Wouters, 1999).

Then in 1959 Gene received a letter from Joshua Lederberg who had recently received the Nobel Prize (Lederberg, 2000). He had read Gene's 1955 paper in Science and wrote to him asking what had become of the idea. Lederberg said he could have used such a tool himself to see if there had been any follow up work on a previous paper, the very task that a citation index was designed to do. There ensued an exchange of letters between the two that had a decisive effect on the development of the citation index (Fig. 3).

The sequence of letters shows how Gene's thinking evolved on citation indexing, and some of the paths not taken. The basic idea of a comprehensive unified citation index outlined in the 1955 paper appealed to Lederberg. But Gene worried about how such a broad approach could appeal to more specialized communities such as geneticists or journal publishers. Should there be some kind of selection of references to specific journals or papers based on a scanning of reference lists? Should all references from general journals be captured and then select from these an index just for genetics? Or should the index be based on a broader scanning of references, say from all CC journals, but restricted to general science journals as cited targets? Should the index be sliced up by cited journal and provided separately to publishers?

In addition, Gene wondered if the citing sentences should be classified in some manner, or perhaps a page or reference number given to allow users to find where the citation appeared in the article (Lederberg, 2000, 55–57). Should there be coding of references by function, such as confirmation or refutation, or by type of use made by the citing author, or perhaps an indication of the section of the paper the citation came from? He was toying with the idea that knowing the specific citing passage could be very useful, recalling his Welch project study on using review papers as a means of indexing papers they cite.

Lederberg, for his part, was skeptical of many of these qualified or restricted approaches and urged Gene to stick to the original plan of a unified index and full coverage of a set of journals. He urged him not to pursue some of the more intellectually challenging approaches like coding citations by function, but rather to keep it simple and just capture the citing and cited identifiers with minimal additional coding. Lederberg suggested going to NIH with the full concept and felt that they would see the benefits of being able to see how scientific papers had been followed up on. He also brought up the idea that NIH could use such an index in evaluating its "impact on scientific progress". Later on, Gene could explore the

more in-depth research on the nature of citation. “I feel”, he wrote, “a good general CI will be of greater value to Genetics than a too specialized run that sticks too closely to the discipline.” (Lederberg, 2000, 63). The submission of proposals both to NIH’s genetics study section and NSF were ultimately successful. Due to later changes in rules that prohibited NIH giving grants to companies, the money had to be transferred to NSF and converted to a contract.

It is interesting to speculate on what might have happened if Gene had decided to pursue some of the refinements of citation indexing described in his letters to Lederberg, such as coding reference locations within the text or citation function. Clearly adopting any of these refinements would have vastly increased the production effort and probably endangered the whole project. In the first citation index for 1961 and in all subsequent indexes, there is no indication where within the citing paper the citation occurs, and citing items are only identified by initial page. This simplification made it possible to scale up the index through automation without introducing the need for sophisticated indexing.

More recently, of course, issues around how authors cite have become a major research topic under the general rubric of citation context analysis (Small, 1982), and with the advent of more extensive access to full text in electronic form, Gene’s original vision of a combined citation and linguistic analysis looks more and more like an attainable goal. In later writings he seemed aware of the possibility. In a 1999 tribute to the late Fred Kochen, he wrote: “It is already possible to use citation links, that is, references, to go back and forth from indexes to full-text journals.” (Garfield, 1999)

In 1959 Lederberg also backed up Gene’s idea that citation indexing would be valuable for locating interdisciplinary work. The 1955 paper had stated that “cross-fertilization of subject fields is one of our most important problems in science literature.” Lederberg had complained: “I have to spend a fair amount of effort in reading the literature of collateral fields and it is infuriating how often I have been stumped in trying to update a topic, where your scheme would have been just the solution!” (Lederberg, 2000, 39) Lederberg’s own field of genetics was, he thought, especially suited to citation indexing due to its multidisciplinary nature, involving contributions from disciplines such as biochemistry, statistics, agriculture and medicine. As it turned out, the Genetics Citation Index was created as a subset of the 1961 multidisciplinary index that covered 613 source journals. In addition to a single year genetics subset, an experimental five year genetics index was created covering 38 journals, as was a fifteen year index covering three journals (Garfield & Sher, 1963).

The creation of these subset indexes for genetics, however, proved to be far from straight forward, involving selecting citation records based on both genetics journals and authors (whether citing or cited), matching against specially compiled lists of genetics researchers and journals. Henceforth, the company decided to stick to the original idea of a unified, multidisciplinary citation index covering a selected set of source journals from all fields of science for a single year. As successive annual indexes were compiled, the citations could cross chronological as well as disciplinary boundaries. Lederberg suggested the product be called the *Science Citation Index* (SCI).

An important technical innovation of the first citation index was the introduction of methods to unify cited references. This effort was led by Irv Sher, ISI’s first director of research (Garfield, 2001). It turned out, that authors cited papers in different ways using different journal abbreviations and different spellings of author names. Some method was needed to bring together these variants. Otherwise, it would not be possible to gather source papers together that cited a given paper, one of the main objectives of a citation index. By using cleverly constructed keys involving various elements of the bibliographic reference, they succeeded in unifying most of these variant forms. In later years this would also enable the matching of cited references with source article records as required for constructing historical networks.

Following the completion of the first annual SCI for 1961, Gene attempted to get NSF funding for the printing and distribution of the annual index. When this request was turned down, the company had to make the difficult and risky decision whether to fund this effort themselves. As it turned out, initial sales of the SCI were weak, partly due to its high price, and the product lost money for several years. In 1965 he was advised to seek investors from Wall Street which led to his selling 20 percent of the company for half a million dollars. In retrospect, Gene said, this outside money was not needed and the SCI eventually became profitable. The outstanding shares posed problems in later years when a large publisher attempted to take over the company.

By the mid-‘60 s the availability of weekly updates of citation data enabled the creation of another current awareness product, the Automatic Subject and Citation Alert, or ASCA report. This was a weekly printout of articles matching a search profile which was submitted by the user. The system was written by Irv Sher and was able to retrieve articles using complex Boolean combinations, what Gene called a “Chinese menu” of key words, authors, and cited references. Despite Gene’s enthusiastic support, this product did not take off the way he had hoped, in part due to the difficulty of getting scientists to submit profiles, and was eventually made obsolete by on-line search systems (Fig. 4).

Citation indexing was a radical departure from the traditional methods of indexing and abstracting employed by discipline-based services like the established chemical and biological services which were based on finding the best nomenclature or indexing terms to describe a scientific article, but ignoring the genealogical aspects of the article captured in the cited references. The citation index was the first pan-scientific database knit together by scientists’ own handiwork. Scholars still debate what a citation means, whether it represents “influence”, “usage”, “tradition”, or just window dressing. But it seems clear that Gene was aiming for something higher that spoke to the way science was knit together, and the very social nature of that interdependence. Perhaps in simplest terms it represented for him the transmission of knowledge between scientists, somewhat analogous to the passing of genetic information from parent to offspring.

Fig. 4. Irv Sher, ISI's first director of research.

7. Historiographs

Gene was able to illustrate this knitting together of ideas over time through the concept of the "historiograph", a graphical representation of citation relationships between scientific papers covering several generations. The idea had come from Gordon Allen at NIH who suggested in a letter to Gene in 1960 that network diagrams could be used to show historical citation relationships and provided an example (Wouters, 1999, 53). Gene responded enthusiastically to this suggestion saying that such an application had not occurred to him. In 1964, Gene and Irv Sher published an extensive report on one such network, for the field of genetics, matching it against the historical account given by Isaac Asimov in his book on the history of genetics (Asimov, 1963; Garfield, Sher, & Sher, 1964). Taken in a collective sense, the historiograph defined a community of researchers, a body of literature, and evolving knowledge on a topic. Finding a clear way to present complex networks, however, proved difficult.

It is significant that Gene's last major research project was to develop software to construct and visualize historiographs called HistCite, thereby automating the process that had been so laboriously carried out in 1964. For this purpose, it was also possible to take advantage of the multi-year cumulation of citation data represented by the Web of Science. The HistCite software that he and a group of programmers from Russia under Alexander Pudovkin created has been used by a number of scholars to analyze the history of research fields (Garfield, Pudovkin, & Istomin, 2002).

8. Journal citation analysis

One of the key questions in creating the citation index was what journals should be covered as "source" journals, that is, journals from which all references should be captured. Estimates of the number of journals in science at the time varied widely from 50,000 and up. But how many of these were important to cover? Financial constraints necessitated that the first citation index cover only about 600 journals. Gene and Lederberg agreed that covering the big multi-disciplinary journals like Science and Nature was a priority, but how to select the others? Critics like John Ziman were quick to point out that some key journals had been left out. As the SCI gained traction in the market, journal publishers and editors clamored to get

their journals covered. Gene had the insight that the most important journals would cite other key journals, but to study that required a new kind of analysis.

Early flow charts were drawn up by Irv Sher for the creation of a journal citation index where the article level citation index was summarized on the cited journal as well as the citing journal. Serious experimentation began in the late 1960s. This summarization transformed the article citation network into a journal network where nodes were either cited or citing journals. Initially, a quarterly sample from the 1969 SCI was used. The biggest obstacle to this work was the variation in the way authors cited journals, necessitating a large scale manual unification of cited journal abbreviations.

It quickly became evident that only a couple of hundred journals of the roughly two thousand journals covered at that time accounted for a majority of the references received. This justified in Gene's mind limiting the coverage of the SCI to a relatively small number of core journals compared to the tens of thousands of journals that were alleged to exist. In his 1972 article in Science on journal citation analysis, he claimed "... a good multidisciplinary journal collection need contain no more than a few hundred titles." (Garfield, 1972) He dubbed this the "law of concentration" (in contrast to Bradford's law of scattering), and maintained that no matter what disciplinary or specialized journals were selected as source journals, the same set of highly cited core journals would emerge (Garfield, 1971).

He also noted that the highly cited journals were also the largest in terms of number of published articles. This led him to explore ways to "discount the effect of size", that is, normalize the journal citation counts for journal size, settling on the ratio of citations received by a journal in a two year period divided by the number of published or citable items in that period which he dubbed the impact factor.

The Journal Citation Reports (JCR) was the culmination of this effort when it became an ISI product in printout form and later a book printed along with the SCI. The JCR also introduced a number of journal metrics besides impact factor, such as the immediacy index, and half-life statistics dealing with the time distribution of citations received or given. These data were used to guide journal selection, and were adopted by journal editors and publishers, as well as by some librarians as measures of a journal's performance. However, they remained controversial within the research assessment community, particularly as a surrogate for assessing the performance of individual papers or scientists. Within ISI, the JCR data were extensively used to carry out custom analyses to study journal coverage in various products or to plan coverage for new products such as the Social Sciences Citation Index. Analysis of specific fields could be performed, such as, starting with the core journals in some field, and summarizing their cited and citing journals. Soon the JCR opened up new opportunities for studying the interaction among journals or journal sets which were taken up by scholars in the new field of scientometrics.

9. Evaluation by citations

In Gene's 1955 paper on citation indexing, the evaluative use of citations was noted but not emphasized. For many years he stressed the primacy of the SCI's use for information retrieval, downplaying its secondary use in evaluation. This may in part have stemmed from a concern that sloppy or inappropriate use of SCI data would reflect badly on the product, and he vigorously defended it against such abuses. He also warned against the use of the impact factor in evaluating individuals. In his view, "Using citations for evaluating people is a very tricky business." (Cawkell & Garfield, 2001). Citation counts depended on, among other things, the field of science, time factors, and nationality, and a proper evaluation of an individual, paper or journal needed to take multiple factors into consideration. In later years he worried that the use of the SCI for evaluation had eclipsed its use for retrieval; in effect, "the tail was wagging the dog". (Garfield, 1998)

He also saw the shortcomings of individual scientists' referencing practice, and sometimes chastised individual scientists for their failure to cite relevant papers, as in the case of Watson and Crick's failure to cite Avery for the identification of DNA as the hereditary substance. At the same time he realized that such omissions were part of the complex competitive social relationships of scientists.

His first systematic use of citation counting was made as part of his study of the history of DNA in 1964 where he used the 1961 citation index to count the number of citations to nodal authors in the DNA historiograph (Garfield et al., 1964). This study also includes comparisons of citation rates of Nobel Prize winners to other genetics authors in the historical network, and presages his later interest in using citation counts to predict future prize winners. The highly skewed nature of the citation count distribution also became apparent. Clearly high citation rate and utility were bound up in an important way (Garfield, 1973). What Gene did achieve was to transform the way people looked at research performance, from simply how many papers were published to how often they were cited.

Despite his reservations toward evaluation, he was not hesitant to use SCI data to celebrate and highlight the achievements of scientists. He regularly published lists of highly cited authors and papers from different fields in his CC editorials. In his project to list the 1000 most cited authors, he opted to list the authors alphabetically rather than rank ordered to avoid the impression that some were more important than others (Garfield, 1981). In 1977 he inaugurated his Citation Classics series which featured commentaries by individual authors of highly cited papers. A few thousand of these commentaries appeared over the years and were reprinted in a series of books.

In a revealing interview with his VP for research, Tony Cawkell, Gene explained his interest in recognizing highly cited scientists: "I came from a socio-cultural-economic family background that cultivated a deep sense of justice. . A lot of people are passed over in the formal reward system of science. . SCI and the citation analysis became for me a vehicle to transform an informal system of recognition into an explicit reward system for science." (Cawkell & Garfield, 2001)

10. An encyclopedia for science

In the lobby of the old ISI building at 3501 Market Street was a holographic etching entitled the "World Brain". This work was commissioned from the artist Gabriel Liebermann. The world brain was an idea proposed by H.G. Wells in a 1938 essay that held particular fascination for Gene, and he wrote often about Wells in earlier papers. Wells's world brain was an idea for an encyclopedia that would synthesize the world's scientific knowledge by combining the existing scientific writings by authorities from all fields, in Wells's words "... knitting all the intellectual workers of the world through a common interest and a common medium of expression into a more and more conscious co-operating unity." (Wells, 1938, 33). It seems clear that, in some sense, Gene regarded SCI as a representation of collective scientific knowledge and a step toward the realization of the world brain encyclopedia. Earlier at library school, he had written a term paper about Paul Otlet's ideas on encyclopedism, and he considered Otlet one of the founding fathers of documentation. In 1981 he would be able to put some of these ideas into operation in a product he called the *Atlas of Science*.

While the historiograph captured the chronological evolution of knowledge, the introduction of co-citation in 1973 opened up the possibility of mapping science in temporal slices or cross sections, and by connecting the major specialties and fields of science, also revealed its interdisciplinary nature (Small & Garfield, 1985). He encouraged the development of co-citation clustering and mapping, and advocated for its introduction into ISI products. Initially this took the form of providing indexing headings for on-line products or specialized indexes such as the Index to Scientific Reviews. Later on, he proposed the idea for an *Atlas of Science* which, initially at least, was to be a compendium of maps and what he called mini-reviews – short summary statements about the nature of a specialty written by scientists or science writers. After a couple of editions appeared in printed form, this product morphed into a series of review journals where the co-citation maps served as a guide to what fields should be reviewed.

11. A science newspaper

Gene had a longstanding interest in creating a newspaper of science and his early ideas date back to the 1960s. His ideas were perhaps stimulated by the success of CC in providing up to date information on what was going on in science. Weekly issues of CC already had the feel of a newspaper. Why not expand the idea? (Garfield, 1975) However, just what such a newspaper would provide underwent many transformations. One early idea was to have a Daily Scientist tabloid that, analogous to stock market listings, would update citations to scientists' papers. Since the company was located on Chestnut Street in Philadelphia in 1961, the name Chestnut Street Journal of Science was floated. Other ideas were to publish articles written for a non-specialist audience, to publish abstracts or even rapid publication of original articles. All of these options, however, would involve a substantial outlay of capital for paper, printing and mailing, and therefore the need for outside investments. In the 1970s, the possibilities of electronic distribution were investigated, modeled after television based systems such as Viewdata or Prestel in Britain (Garfield, 1977). Meanwhile, more and more editorial features were added to the CC front matter in addition to his weekly essays that began in 1962 under the heading "The Informatorium". Features such as Press Digest gave CC more the feel of a news magazine.

Eventually, in the mid-'80 s his ideas gelled around doing a magazine that focused on the business and profession of science, with discussions of science funding, politics, and the job market, and in 1986 *The Scientist* was launched (Garfield, 1986). Together with other new products at the time such as the *Atlas of Science*, *The Scientist* put considerable strain on the company's finances and led in 1988 to Gene's divesting a controlling interest in ISI to an outside investment firm, JPT Holdings, an acronym for the first names of the owners, Joe, Paul and Ted. He later claimed that the new management had misled him into thinking that support for *The Scientist* would continue, but like other newly launched products, this proved not to be the case and the magazine project was terminated. The only option was to continue to support the effort on his own, and spin it off to a separate company which he did in partnership with Vitek Tracz.

12. Gene as boss

We had a memorable first meeting. I had written Mort Malin, ISI's vice president for Corporate Development, and asked if they had a job opening and sent some of my bibliometric work. Gene was coming to New York City on business so I met him in Penn Station. He was wearing orange socks. We went for coffee but he had forgotten to bring money and had to go to a Western Union to have some wired from Philadelphia. We hailed a taxi but then he realized he did not know whether his appointment was north or south on Park Avenue, so we had to find a pay phone. Dropping me off, he asked what kind of a guy I was. I said in my mid-western manner that I was just an ordinary guy. He said "at ISI we only hire extraordinary people." I thought, well, I really blew that one. I nevertheless got the job.

Our relationship got off to a rocky start a few months after I joined the company in 1972. I went to his office with a paper I had written on a new type of analysis you could do with his citation index involving jointly cited papers, what I called co-citation (Small, 1973). His initial reaction was that it was presumptuous of me, an unknown and unpublished scholar, to present him with such a fait accompli. At first I thought I would be fired but when this did not happen, I gained more confidence. I realized he respected you more if you stood up for what you believed in. After this initiation by fire, he accepted me as an independent researcher, and I received his enthusiastic support.

Fig. 5. Portion of the Cathedral of Man mural by Guillermo Granizo showing portraits of Merton, Garfield, de Solla Price, and Lederberg.

He saw that I was interested in using the SCI to study the structure of science and gave me a book he considered pertinent, *Numerical Taxonomy*, a treatise on cluster analysis (Sneath & Sokal, 1973). He encouraged me in my work on clustering the SCI using co-citations, and its application to map science. He generally created an atmosphere in the company conducive to experimentation and innovation. Together with Mort Malin, my boss, we worked on a joint paper on science indicators and participated in a meeting in 1974 at the Institute for Advanced Study in the Behavioral Sciences attended by many luminaries in the sociology of science (Garfield, Malin, & Small, 1977). In 1975 I organized a conference on citation analysis inviting many leading sociologists and bibliometricians which was held in a small conference center in Maryland. Gene brought his saxophone and was heard practicing in his room. I think this was a form of relaxation for him. Years later we worked together on other papers, culminating in a joint paper in 1985 on what we called the "geography of science" which was reprinted in the front matter of the SCI for many years (Small & Garfield, 1985). It also led to our experiments in creating an *Atlas of Science*.

The rank and file employees were an interesting group of creative people including quite a few artists, musicians, writers and non-conformists. One reason for this was that many of the jobs in the company, particularly those in data capture, were relatively routine and repetitive but still required a high degree of literacy. But you could forget your job at the end of the day and pursue your real interests. The other reason was that Gene was drawn to such people and enjoyed being with them, and to some extent identified with them. He had an open door policy and anyone could go to see him. He enjoyed these encounters with employees, and his response to their complaints was usually generous and supportive. This intense engagement with staff fostered a sense of loyalty and dedication. Many of his employees stayed many years at the company because of the collegial atmosphere he created. I am very fond of the inscription he wrote in my copy of the first volume of his multivolume *Essays of an Information Scientist*: "It's a fantastic pleasure to be associated with you in our daily work and in particular as a co-author of these volumes. . Henry, I hope we can get to know each other better in the years to come."

Not only were artists employed at ISI, Gene decorated his new 3501 Market Street building, a building designed specifically for ISI by a prominent post-modern architectural team, Venturi Scott Brown Associates, with murals and art works, including some that were controversial. The mural called the "Cathedral of Man" by Guillermo Granizo featured cameos of people who were influential in his life like Robert Merton, Derek Price, Joshua Lederberg and information greats, including Gene himself, drawn on orange tiles, his favorite color (Fig. 5).

He was also a lover of the complex and colorful yarn art by the Mexican Huichol artist Emeteria Rios Martinez whose work decorated the walls of the building. In 2009 the company under the control of Thomson Reuters decided to vacate the Market street headquarters that bore the unmistakable stamp of his career and personality, to take up occupancy in a non-descript office building on Spring Garden Street. A part of him and us stayed in the old building (Fig. 6).

When he travelled, which was often, he took issues of CC, ASCA reports and a small red notepad on which he would scribble semi-legible notes to employees on things they should work on. When he returned to the office these notes were sent out. Much time was spent deciphering these missives, and trying to figure out how or if to respond. We all had collections of these notes on our desks, always dreading the follow-up or reminder: "did you reply to Dr. so and so? . . .", "was this error corrected? . . ."; "did you write a paper refuting this statement? . . .", "read this and discuss with me". . . Often he would forget what he had asked you to do, but sometimes these follow-ups would mysteriously reappear to our horror. Even years later, he could suddenly ask you out of the blue "did you ever do that research front animation we talked about?"

The extent of his social network became apparent to me when I occasionally accompanied him on road trips. He seemed to know personally every library director, head of department, and researcher along the way. He was almost a celebrity

Fig. 6. ISI headquarters in the late 1970 at 3501 Market Street, Philadelphia, PA designed by Venturi Scott Brown Associates.

in Europe, more so than in the States. This was brought home to me while on a lecture tour of Europe in 1985. We were walking down a dark street in Zurich when out of the shadows came a figure who said, “Good evening, Dr. Garfield”. He was evidently a scientist who had recognized Gene from his picture in CC. The stranger started talking about incidents in Gene’s life, including when he drove a cab in New York, which he had read about in CC essays. Many people we encountered on that trip felt as if they knew him personally through these editorials.

13. Gene as business man

In the late 1950s the company he formed went through several name changes until finally settling on the Institute for Scientific Information (ISI) in 1960. This name was chosen to project more of an academic and non-profit image, making it easier to sell to libraries and individual scientists. The name was suggested to him by the name of a soviet information organization called VINITI, which translates to Soviet All-Union Institute of Scientific and Technical Information (Garfield, 1987). Perhaps by coincidence, Bernal’s book, *The Social Function of Science*, contained a discussion of a proposed organization called Science Information Institute (SII) which could also have subconsciously influenced his choice (Bernal, 1939, Appendix 8). As a young man he had been given a copy of Bernal’s book by one of his socialist uncles, and Gene considered Bernal one of his intellectual forbearers, endowing an award in his honor at the Society for Social Study of Science (Garfield, 1982) (Fig. 7).

Fig. 7. Gene Garfield and J.D. Bernal in 1958 at the International Conference on Scientific Information, Washington, DC.

Gene considered himself a “super-salesman” and promoter, and the early success of products like CC and the SCI were largely due to his sales efforts. Sometimes his marketing efforts went too far, for example, when he had fortune cookies made up containing the message “the SCI makes you a successful scientist”. The FASEB society would not allow him to distribute the cookies at their meeting.

His approach to products was not that of a conventional business man, but rather as a visionary and innovator. New products often teetered on the edge of profitability. He retained controlling interest in the company and fended off a number of attempts to wrest control from him. If he believed in a product idea and thought it would be useful to customers, there was no dissuading him from pursuing it even if it lost money. Eventually, he thought, customers would see its merits. If someone told him it could not be done, he was even more determined. Some of his early products like the *Index Chemicus* did not turn a profit for many years. In the beginning, he would use the profits from a successful product like CC to fund new products like the SCI which took several years to be profitable.

This approach led to many conflicts within the company. For example, in 1969 a group of four executives – Gene called them the four horsemen of the apocalypse – walked out over his unwillingness to focus on profitability, and formed their own company to compete with ISI. The new company, however, failed and one executive, Irv Sher, rejoined ISI. Gene would later comment how difficult it was to run a for-profit company like a non-profit. He was aware that he had a reputation as a risk taker, or “crapshooter” as he called himself (Garfield, 1987), and admitted that there was an element of ego in his decisions (Cawkell & Garfield, 2001). Eventually, stretched financially, having too many products for which a market had yet to be developed and tired of day to day management, he decided to sell the company (Garfield, 1997).

He travelled often to the Soviet Union to sell products and give talks and he got to know a number of prominent scientists and dissidents like V.V. Nalimov, who had written a book entitled *Naukometria* which translates to scientometrics. Eventually Tibor Braun at the Hungarian Academy of Sciences founded the first journal in the new field using that name. However, some communist countries would only buy one copy of an ISI product, and then photocopy it for distribution. The CC editorials he wrote on topics in American society were interesting to foreigners, but the Soviets were paranoid and heavily censored them.

14. Gene as humanitarian and philanthropist

Gene believed strongly in the positive impact of science on society and the social returns of investing in scientific research, later sponsoring an award for the best paper on the topic at Research! America. He also strongly believed that information products like CC and SCI accelerated the progress of science and ultimately led to economic growth and human welfare. Despite resistance from publishers, he thought open access to the scientific literature would ultimately be realized. He also believed that citations were a form of symbolic reward or currency for scientists which would help them in their careers. As a champion of both private enterprise and social welfare, he was not opposed to government sponsorship of information systems as long as they did not unfairly compete with his own products. He benefited from some government support but was critical of policies that made it more difficult for private companies to obtain that support. His social consciousness is evident in his support of the ACLU.

The child care center he built behind his new headquarters building on Market Street enabled employees to keep their children nearby during working hours, and was perhaps inspired by his experience of being raised by a single mother and also having been a single parent himself. He supported children in other ways, through Project Home in Philadelphia dedicated to alleviating poverty and homelessness, and his sponsorship of Opera Company of Philadelphia rehearsals for school children. He also supported young scholars with doctoral dissertation awards in various library and information schools and societies, as well as a medical scholarship for minority students. When the ISSI society was formed at the 1993 meeting in East Berlin, he agreed to sponsor a doctoral dissertation award.

15. Summation

The reasons for Gene’s enormous influence are many. He began his professional career when computing was in its infancy and information services were almost exclusively provided in printed form. His career spanned the great revolution in computing power culminating in the invention of the internet. The information products he developed were ideally suited to electronic delivery, and their adaptation to the new medium gave ISI tremendous impetus. Equally important was the rapid expansion of science in the post-war era, including a growing government funding for science after Sputnik and the Watson and Crick revolution in biology. His early products were aimed at improving scientists’ access to information. But the most important factor for his success, I believe, was his ability to envision how relatively simple yet powerful ideas on the organization and delivery of bibliographic data could transform the information seeking behavior of users.

He concluded his first letter to Lederberg in 1959 with words that tell us something about Gene’s motivation and idealism: “I have great faith that the citation index will one day be a spur to many new scientific discoveries in the service of mankind.” (Lederberg, 2000, 42)

In 2007 Gene participated in Vitek Tracz’s “Web of Stories” project in which he spoke informally about his life and career on videotape (Garfield, 2007). I was fortunate to be his interlocutor. This turned out to be a marathon session over the course of three days and in these videos you can see his true personality, his joy of life, his incredible memory for names and events, his intellect, and sense of humor.

In talking about how research scientists regard literature searches, he said: "We used to talk about, do scientists really want to do literature searches?. . I said to a librarian, do you think that the average scientist who comes to you is happy when you come up with papers that anticipate his ideas? He's looking to you to prove that it's a novel idea, not that it's unoriginal. . That's one of the dilemmas that we face in using information for discovery purposes. . But people like Josh Lederberg always pointed out that if you're a mature scientist eventually you get over that and his talent, and people like him, is framing questions for which you give them partial answers. . If you're working in the field of genetics if somebody answers some fundamental question, that's what you give people prizes for. But you don't get upset by the fact that somebody like Jim Watson, you know, identified the double helix. You go on from there and you go to the next step, right? So it's your attitude, being mature about it, how you use and await discoveries. There's plenty more to be discovered after your great idea proves to be not so original any more. . That's what make science goes around." (Garfield, 2007, 81)

Gene goes on to discuss his contributions, and that people give him credit for things he did not do. He admitted he was not much of a theoretician and wished he had made more discoveries. He joked that even the so-called Garfield constant is always changing. "You'd like to think that you spent your life doing things that help improve the condition of man. . So I think that the challenges will remain and I hope there will always be interesting and useful questions that people will keep on answering. That there will never be an end to the number of new questions that could be asked. The unanswered questions of science: that was another one of the projects we never finished." (Garfield, 2007, 82)

Ironically, even in his philosophical musing he was reminded of an unfinished project. There is no doubt that the information products he has given us will, as long as they survive, supply us and future generations of scientists with an unending stream of questions and partial answers that lead to more questions, and this is the real legacy of Gene Garfield.

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Henry Small
SciTech Strategies, Inc., 105 Rolling Road, Bala Cynwyd, PA 19004, USA
E-mail address: hsmall@mapofscience.com
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A tribute to Eugene Garfield – Discovering the intellectual base of his discipline

Olle Persson

Inforsk, Umeå University, SE-901 87 Umeå, Sweden

THE number of citations that a scientific paper gets from other papers is a well-known indicator of scientific impact. In any discipline, we can expect to find a small number of papers that are frequently cited and a large set that are cited only once or twice. Many papers may not be cited at all. Similarly if we distribute citations among the authors of papers we usually get a core of highly influential individuals.

Citation analysis is a well-established research method in the field of science studies. *Scientometrics* is one of the core journals of this research field reporting on various types of bibliometric studies, most of them including the study of citations. Since its beginning in 1978, *Scientometrics* has published 1062 papers till the end of 1999. The most cited authors, or to be more exact the most cited first authors, are listed in Table 1. At the top we find D. Price and E. Garfield who are the founders of the scientometric research field. Price is cited in every third paper and Garfield in every fourth. Below them there are authors having made substantial contributions to the field and most of them have already received the 'Derek Price Award'. My impression is that this list has great face validity, and it is really hard to come up with other names that should enter the first ten ranks or so.

Then if we want to discover the structure of this research field we can count the number of times the listed authors appear together in the same reference lists of papers. This technique is called co-citation analysis, first discovered by Henry Small[1], and assumes that authors that are frequently co-cited are more related in terms of specialization than authors that seldom or never occur in the same reference list.

A co-citation matrix was constructed that gives the number of papers in which each pair of authors has been co-cited. Then this matrix was taken as input to a Multi Dimensional Scaling algorithm (MDS), that led to a two-dimensional graphical representation of the co-citation matrix. Each author got an *x*- and *y*-coordinate which defines the map. Distances between the authors are shorter the more co-cited they are, since co-citation frequencies are treated as similarities by the MDS-routine.

The map (Figure 1), drawn using bibliometric software BIBEXCEL[2], shows the positions of the listed authors relative to one another. The area of the circles is proportional to the citation frequency, and the lines between them indicate if they are co-cited, and the width of the lines indicates the co-citation frequency.

At the very centre we find Price and Garfield. To the right there is a concentration of US authors, including well-known sociologists of science Merton, Cole and Cole, Zuckerman and Crane and information scientists Small, Moravcsik and Griffith. The integration of scientometrics and sociology of science is not visible in the left part of the map, which contains mostly European researchers

Table 1. Most cited first authors in the 1062 papers published in *Scientometrics* from its start in 1978 to 1999

Number of citations	Cited first author
343	Price, D.
245	Garfield, E.*
178	Narin, F.*
155	Schubert, A.*
152	Small, H.*
124	Braun, T.*
96	Moed, H. F.*
83	Frame, J. D.
82	Moravcsik, M. J.*
78	Egghe, L.
73	Martin, B. R.*
71	Callon, M.
70	Leydesdorff, L.
69	Merton, R. K.*
61	Cole, S.
56	Van Raan, A. F. J.*
56	Cole, J. R.
56	Zuckerman, H.
55	Vlachy, J.*
55	Brookes, B. C.*
50	Glanzel, W.*
49	Crane, D.
49	Bradford, S. C.
48	Irvine, J.*
48	Carpenter, M. P.
47	Griffith, B. C.*
46	Lotka, A. J.
45	Nederhof, A. J.
43	Vinkler, P.
43	Lawani, S. M.
42	Luukkonen, T.
41	Arunachalam, S.
40	Lindsey, D.
40	Beaver, D. D.

*Indicates authors who have received the 'Derek Price Award'.

e-mail: olle.person@soc.umu.se

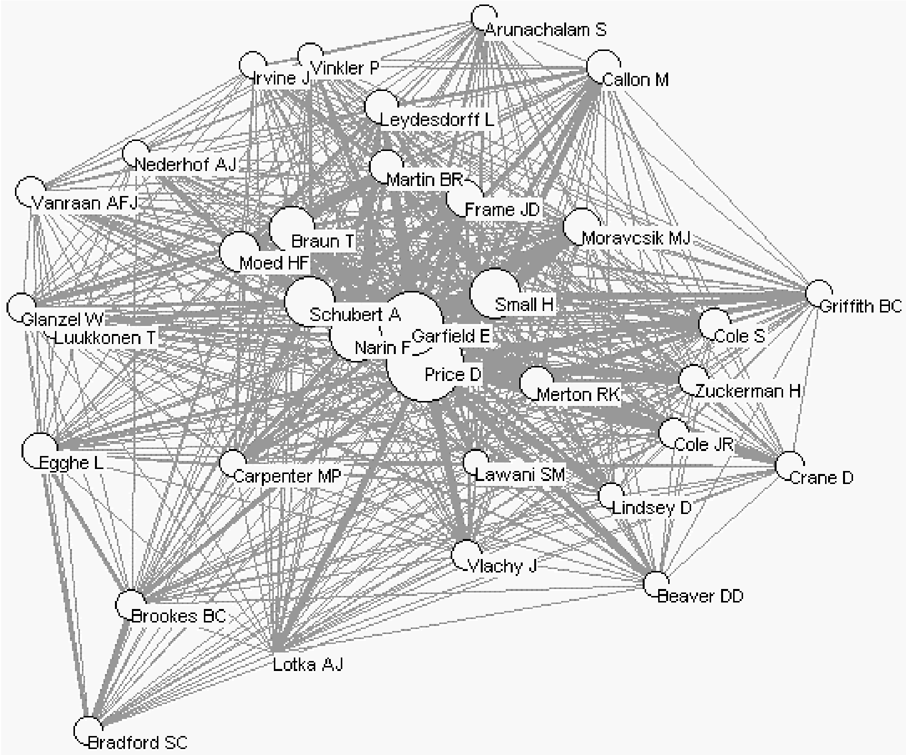


Figure 1. Intellectual base of scientometrics 1978–1999. First author co-citations made by 1062 papers in the journal *Scientometrics*.

specializing in science indicators and science evaluation. Francis Narin appears to be the leader of this segment and is placed to the left of Garfield and Price. The lower left part forms a small group of authors, mostly practitioners of library science, specializing in scientometric distributions (Bradford, Lotka, Brookes, Egghe).

To conclude, the field of scientometrics is structured by geography and specialization. There is a clear divide between US and Europe, although the links show several interconnections. The founding fathers of the field, Garfield and Price, appear to keep the field together which would otherwise split even more.

Co-citation-based mapping is one visualization technique that profits from Garfield's invention of citation indexing which assumes that cited documents are valid representations of the content of research. Without him we could simply not see what we now can!

1. Small, H., *J. Am. Soc. Inf. Sci.*, 1973, **24**, 265–269.
2. Persson, O., BIBEXCEL, a tool-box for scientometric analysis; http://www.umu.se/inforsk/Bibexcel.

Dedication

A Book: *Publishing a RESEARCH PAPER*

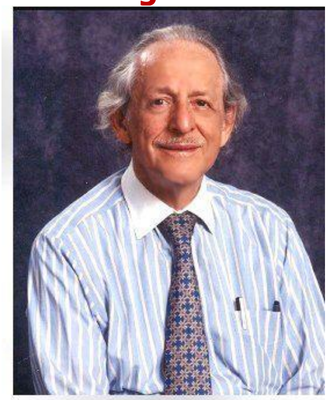
❖ The Faculty of Management Studies had published the cited book in 2012.

❖ The book was dedicated to Prof Dr Eugene Garfield.

❖ The book contains 18 chapters written by 18 'Research Scholars'.

❖ The second edition of the book was published in 2018, the 'Silver Jubilee Year' of the Faculty of Management Studies.

Prof Dr Eugene Garfield



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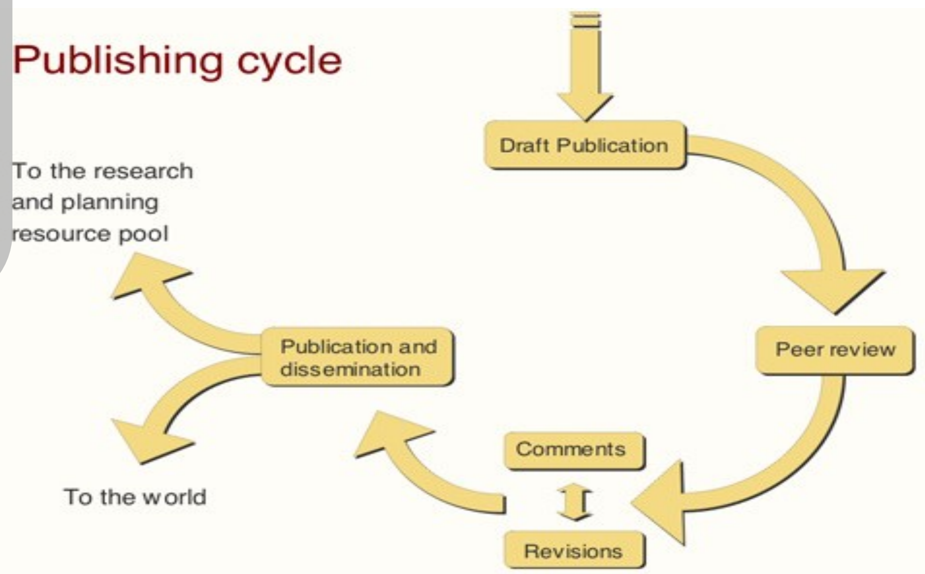
Here some important details of the cited book are reproduced for information !

Silver Jubilee Edition

Publishing a RESEARCH PAPER

A PANORAMIC VIEW



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Faculty of Management Studies

Dr. M.G.R.
EDUCATIONAL AND RESEARCH INSTITUTE
(Deemed to be University)
Maduravoyal, Chennai - 600 095. Tamilnadu. India.
(An ISO 9001 : 2015 Certified Institution)

Publishing a

Research Paper

A Panoramic View

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FACULTY OF MANAGEMENT STUDIES

Dr MGR

Educational and Research Institute

(Deemed to be University)

Maduravoyal, Chennai – 600 095

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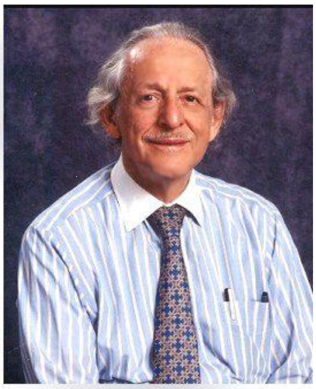


Prof Dr Eugene Garfield

Father of 'Citation Index'

Grandfather of Google

Bi-Decennial Year 2013 Publications

Foreword

The process of writing a research paper though a complex task is the most rewarding experience one may encounter in the academic field. Experience and practice area absolutely essential to become a good researcher and writer of a quality research paper. Even eminent research scholars find it difficult to write a research paper unless they learn by experience how to write a research paper. Therefore a scholar can achieve academic excellence through his/her research and publication, provided he/she has the qualities like diligence, practice, experience, willingness to learn with patience.

This book is designed to help the research scholars find out answers for the complicated questions. If the reader follows the process and adheres to the correct documentation style and the supervisor's directions, a scholar should end up with a mechanically correct research paper or documented essay. However, that does not assure a quality document or a high grade. An effective research paper also smoothly integrates the research findings into unified, coherent paragraphs. Like all other well written documents, the research paper is clearly and logically organized, incorporating scholar's ideas and innovations. Grammar, punctuation, usage, and spelling are accurate.

Present day scholars are under tremendous pressure from various quarters, viz., peers, universities, academics and other educational regulatory authorities. They feel the pressure either due to lack of time or lack of knowledge or both. A scholar faces a tough task of getting himself qualified in the profession within a time frame and competes in the field of career development. In a highly competitive academic market, a scholar has to, sometimes, compromise quality and ethics. Unfortunately, over the time, the quality and honesty of the most of the research supervisors are getting eroded and thus, diluting the quality of academic research.

In the dearth of quality of knowledge and scholarship of both the scholars and supervisors, a single source, as this book, appears to be a boon for any research scholar who sincerely seeks research acumen. It is quite new and innovative style in which eighteen research scholars have contributed each chapter which are highly relevant and very useful to the scholars. The topic of each chapter and the arrangement of chapters are logical. They speak for themselves: [01] Ethical Issues in Academic Research; [02] Reading a Research Paper; [03] Evaluating a Research Paper; [04] Evaluating Information; [05] Research Paper vis-a-vis Survey of Literature; [06] Journal Impact Factor; [07] Citation Styles; [08] APA Citation Style; [09] Open Access Journals; [10] Citation Indexes; [11] Structure of a Research Paper; [12] Plagiarism @ Research; [13] Writing a Paper : Timeline; [14] 100 Tips for Publishing a Paper; [15] Writing a Research Paper; [16] Writing an Annotated Bibliography; [17] Selecting a Journal; and [18] Publishing a Research Paper.

Another significant feature is that each chapter has a list of selected 'keywords'. These keywords would enable the readers to proceed further in the ocean of knowledge and enrich the readers' quality of scholarship. The idea of appending a Glossary and an annotated Webliography at the end of these 18 chapters is highly thoughtful and both would facilitate the scholars in pursuing the quality research in cheerful academic career.

I do appreciate the editors in bringing out an excellent collection of highly informative papers and I have no doubt that this attempt would help the research fraternity in the long way in their pursuit of knowledge.

Chennai – 600 095
02 October 2012

Dr P Kaliyaperumal
Dean-Faculty of Management Studies
Dr MGR Educational and Research Institute

Preface (I Edition)

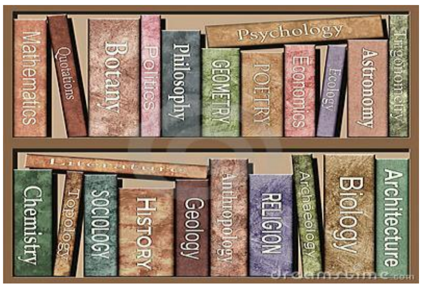
An objective of organizing a research paper is to allow people to read your work selectively. When a scholar researches a topic, he/she may be interested in just the methods, a specific result, the interpretation, or perhaps just wants to see a summary of the paper to determine if it is relevant to the research study.

A good research paper addresses a specific research question. The research question—or study objective or main research hypothesis—is the central organizing principle of the paper. Whatever relates to the research question belongs in the paper; the rest doesn't. This is perhaps obvious when the paper reports on a well-planned research project.

Generally, only one main research question should be addressed in a paper (secondary but related questions are allowed). If a project allows the scholar to explore several distinct research questions, write several papers. For instance, if the scholar measured the impact of obtaining written consent on patient satisfaction at a specialized clinic using a newly developed questionnaire, he/she may want to write one paper on the questionnaire development and validation, and another on the impact of the intervention. The idea is not to split results into 'least publishable units', a practice that is rightly decried, but rather into 'optimally publishable units'.

The key parameters of a high quality research article include:

• An introduction to the nature of the study – this should be written in an easily accessible manner, it should be reasonably brief but with sufficient detail to interest the readers, particularly the target audience.



• A literature review – by its very nature, research perpetuates itself. There is no end point to research and therefore it will be the case that a research article builds on previous knowledge and understanding drawn from prior research. The authors of the research article need to show what research they are building on in their article. This does not mean that any and all literature should be quoted or cited –

but the readers need to know the pedagogical underpinning of the research, the ‘school of thought’ that has influenced the direction of the research.

• The development of a hypotheses and the research plan – should be clear to the reader.

• The design of the study should be articulated well and the research should have been carried out in an ethical manner.

• Appropriate interpretation of the results – results should not be over interpreted and analyzed because all research has limitations and the authors need to recognize these limitations.

• Sufficient replication and duplication of the study – too many research articles are based on a one off study and this is problematic. Research outcomes should be capable of being replicated and duplicated. There is very often a temptation to write up a one-off study, over-interpret and make sweeping generalizations.

• The research should be authentic.

A studious research scholar, who does his job with a great zeal and assiduity, should know the difference between a popular journal and a scholarly journal, if he really intends to go and seek his article published in a quality journal of international repute. The following table gives a bird’s eye view.

Criteria	Scholarly Publications	Popular Publications
Appearance	simple layout with serious appearance and dense text - main attraction is the articles	colorful, glossy, photos, illustrations, advertisements
Audience	scholars, researchers, students and well-educated public	general public
Authors	scholars, professional practitioners	journalists, professional and amateur writers who lack subject expertise
Content	in depth analysis or extensive overview of a topic	simple discussions of news, entertainment, or other popular subjects
Review Process	works published after review by credible scholars in the discipline (peer review)	works reviewed by publication editors or purchased
Research Documentation	footnotes and bibliographies cite the author's research	information sources are rarely cited
Language	technical language in the	simple, non-technical

	specialized vocabulary of the discipline covered	language
Purpose/Intent	Present cutting-edge research specific to the field	to inform or entertain the reader, sell products, and/or promote a viewpoint
Examples	Canadian Journal of Political Science, Shakespeare Quarterly, French Historical Studies	Newsweek, Sports Illustrated, Vogue, People

Therefore, job of publishing a research article itself seems to be a research itself. A scholar has to know a lot about the journals, process of publishing a research article, Impact Factors, and so on.

Thus an idea of this book - narrating about the several aspects and the stages involved in publishing a research article in a reputed journal of international standard – is inspired by the genius and contribution of Dr Eugene Garfield, a colossus in the field of 'citation index'. The tedious task of conceiving a book [about a research paper!] has been meticulously planned, designed and executed. After serious discussions and an enriched academic thought process, finality is arrived at – in deciding the number, title of these chapters and the arrangement thereof. Then another laborious stage commenced – in identifying and allotting the most appropriate chapters to each research scholar. This stage proved to be highly interesting and challenging! A great experience indeed. A final addition – an annotated webliography – is enriching this small volume.

The editors are much obliged to the Faculty of Management Studies of the University for having agreed to publish - a highly appreciative gesture benefiting the research fraternity. Also, editors place their gratefulness and acknowledge the encouraging acceptance of Dr P Kaliyaperumal, Dean of the Faculty of Management Studies for writing a Foreword.

It is hoped that the young and enthusiastic research scholars as well as fresh and new research supervisors would find this volume most interesting and useful. Editors warmly welcome any suggestions for the useful enrichment of the publication from academic fraternity.

13 October 2012
Chennai – 600 095 **Editors**

Preface

Silver Jubilee Year Edition

The First edition of this book was published during the Bi-decennial year (2013) of the Faculty of Management Studies. That was an unique and specially featured edition in which 17 research scholars of our University had contributed one chapter each.

We are happy to know that all these 17 research scholars had completed their PhD studies and obtained the degrees from the respective universities.

Recently almost all the universities insist (of course due to the revised regulations of University Grants Commission, UGC), that all teaching faculty should initiate steps to enrol themselves in PhD program and get the degree at the earliest. Naturally, writing and publishing papers – as a corollary – by research scholars has become obligatory.

Therefore, these trends have necessitated the revision of the earlier book. Now, Annotated Webliography has been extensively revised and duly enlarged. More web portals of international reputed journals are added. The earlier edition was duly dedicated to Prof Dr Eugene Garfield, considered father of citation index and grandfather of Google. The legend had expired in 2017 at the age of 92. Therefore, a special Annexure – III is added in this edition featuring the highlights of his contributions to the academic fraternity.

We hope that this silver jubilee edition – duly revised and enlarged - would be an important and useful resource to the research scholars and other stakeholders in the academia.

25 Sep 2018 Editorial Board

Publishing a

Research Paper

Silver Jubilee Edition

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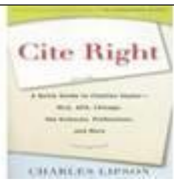
060	**Citation Styles** Lists and narrates various citation styles used by academic fraternity and their distinguishing features. Details the needs and ranges of citation styles. Also lists several citation tools available in the web.	
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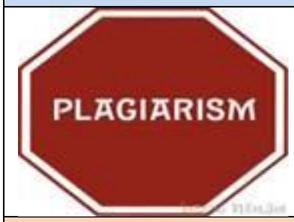	**Plagiarism @ Research** Explains the various types of plagiarism, strategies for avoiding the plagiarism and provides an elaborate illustrative examples of plagiarism. Online exercise on plagiarism is available.	**117**
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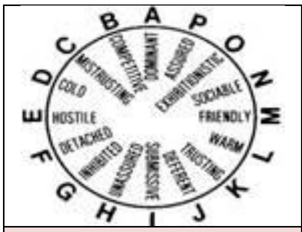	**Writing an Annotated Bibliography** Illustrates various types of annotated bibliographies and the strategies involved in developing a good quality annotated bibliography. Purpose and usefulness of the annotated bibliography are narrated.	**159**
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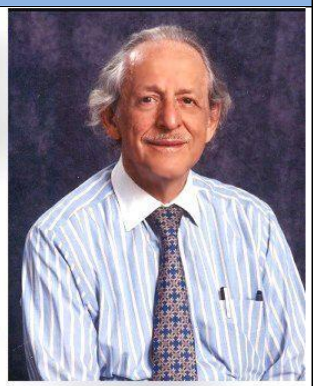
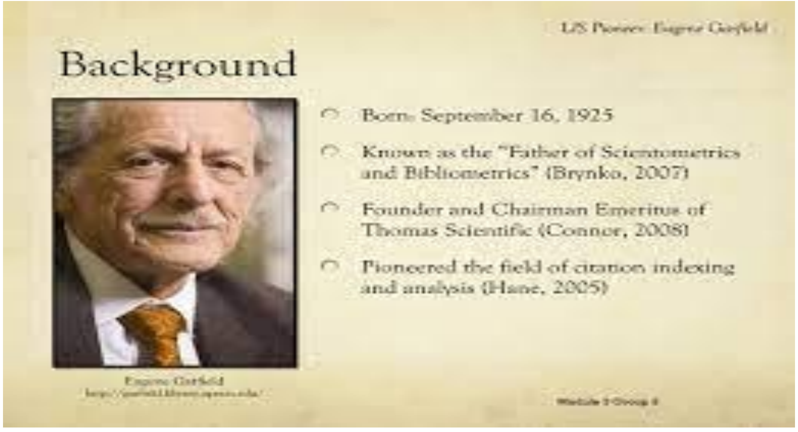
237	**Annexure – III : Grandfather of Google** Eugene Garfield (1925 – 2017) was one of the most influential figures in the world of library and information science in the second half of the 20th century. He pioneered citation indexing in the sciences and scholarly journal literature. Garfield came to see the impact factor as a mixed blessing, "like nuclear energy". Although he felt that citation indexing and the impact factor could be remedies for the limitations of peer review, he was uncomfortable with their misuse as performance indicators.	

Prof Dr Eugene Garfield

Figuratively



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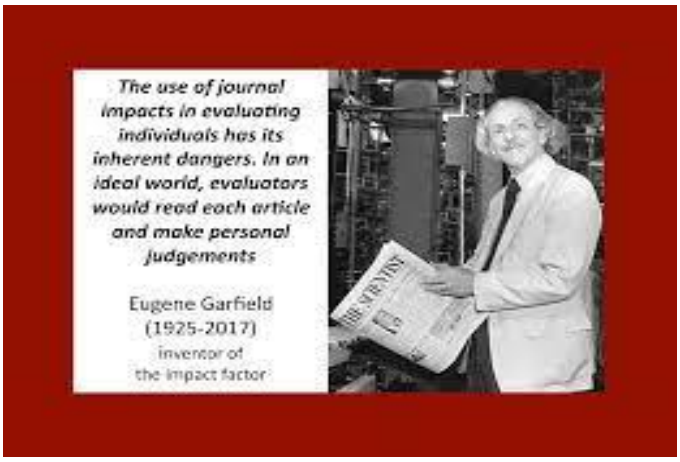

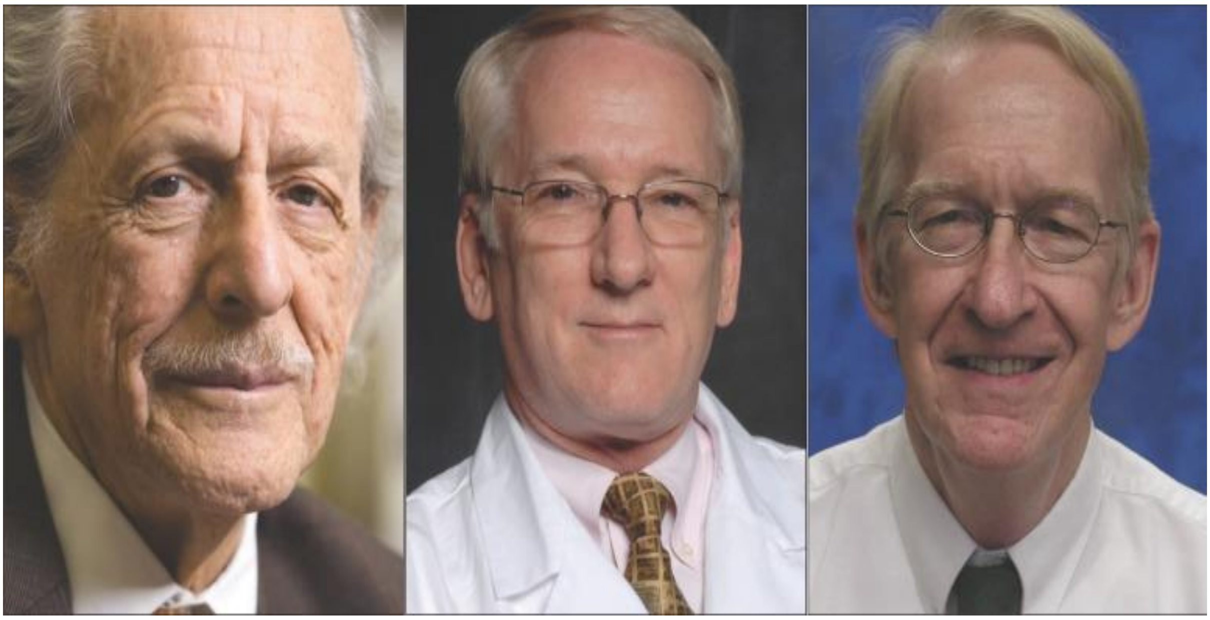

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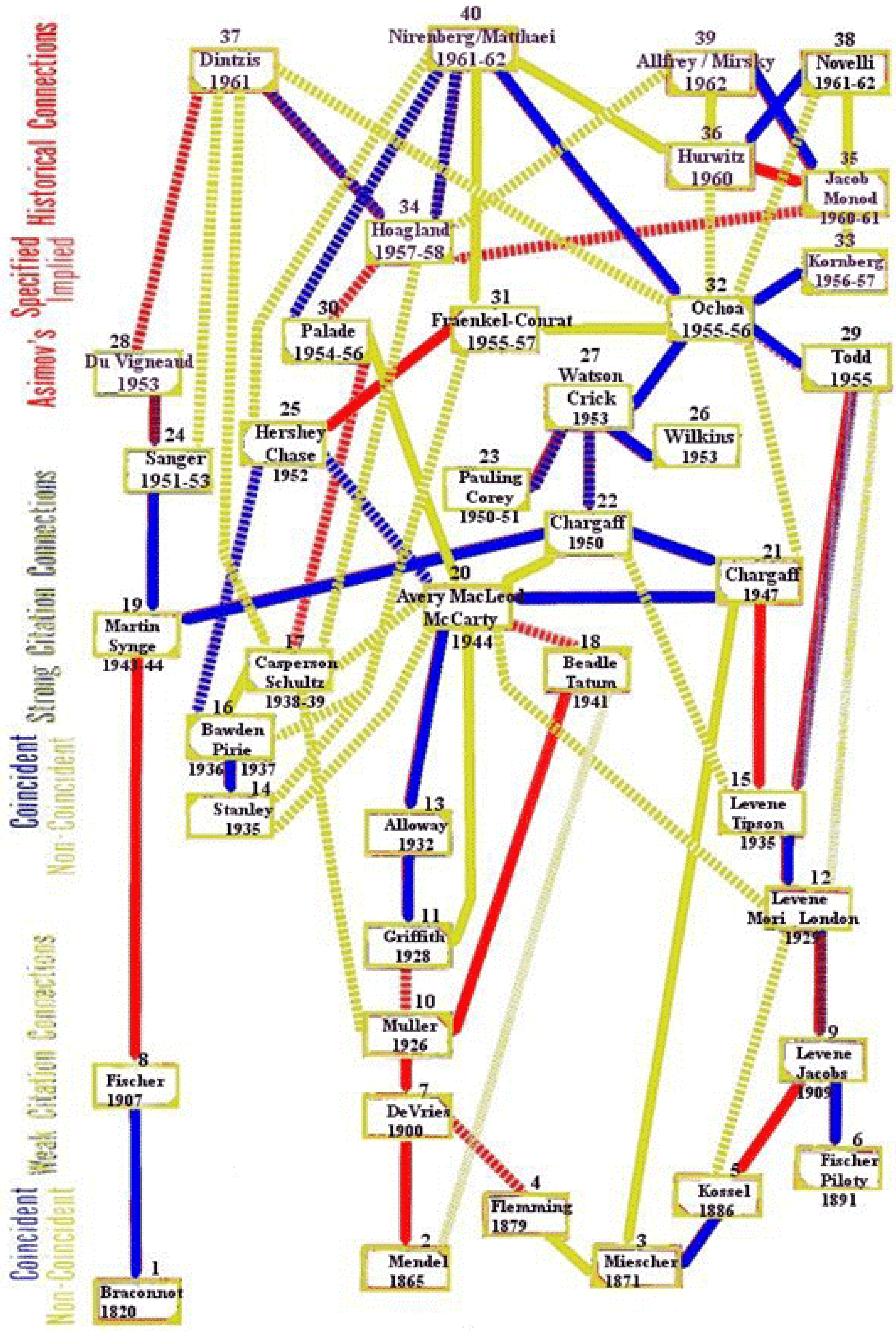
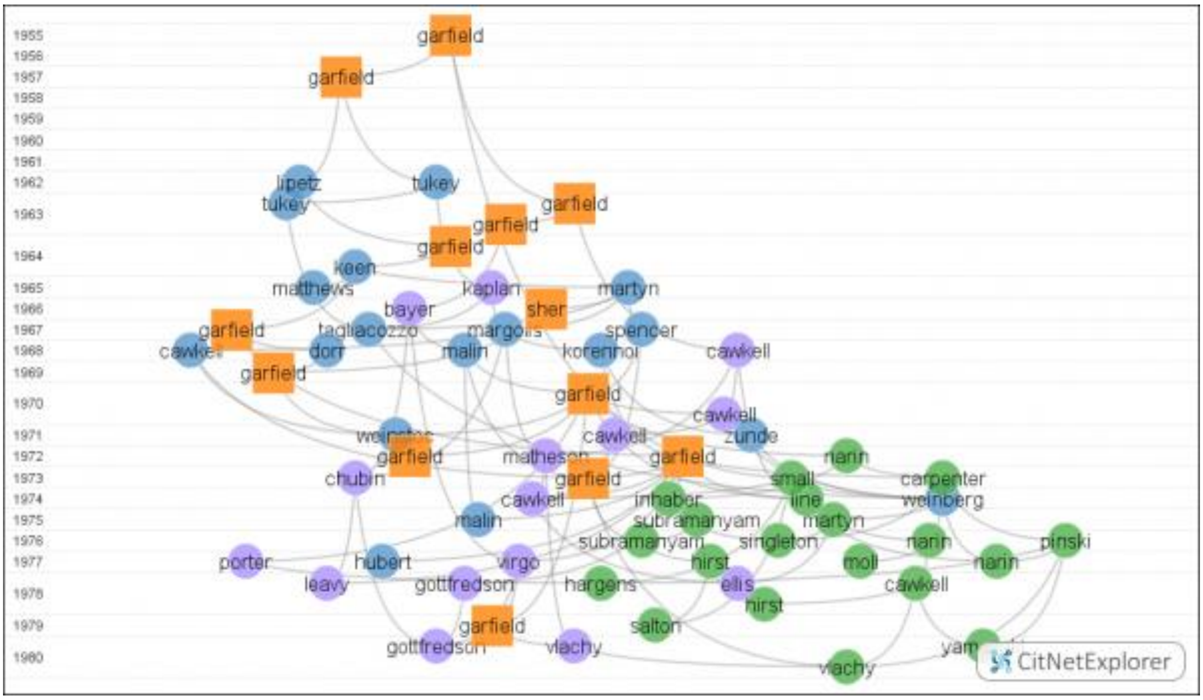


Eugene Garfield and the Algorithmic Historiography:
Co-Words, Co-Authors, and Journal Names

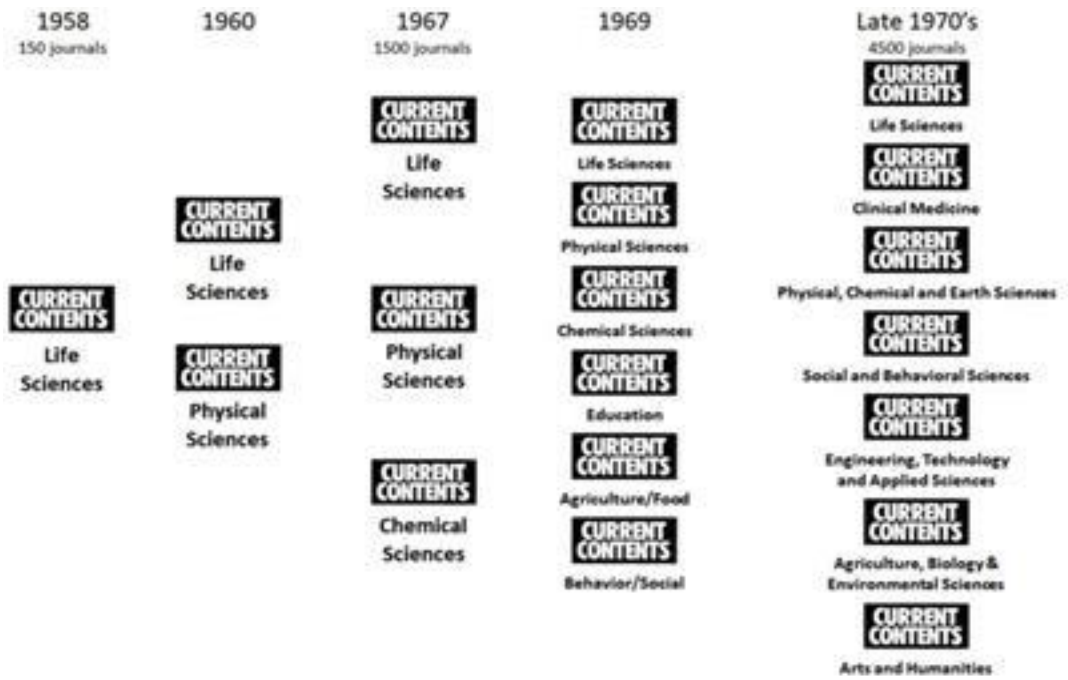


Early influence of Eugene Garfield's work. *Highly cited publications by Garfield (orange squares) and selected publications citing Garfield's work (first generation in blue; second generation in purple and green). Restricted to publications indexed in Web of Science in the period 1955-1980. Only core citation links are shown.*

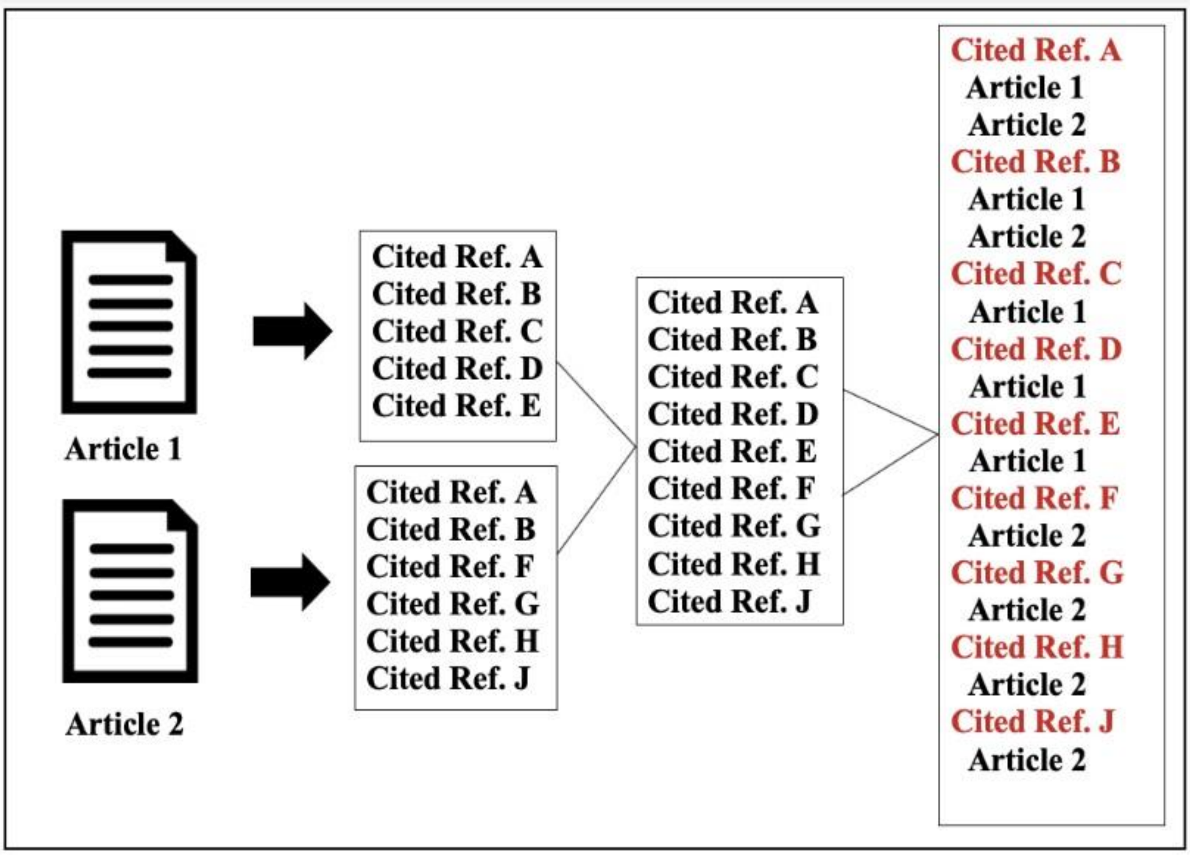
Robert Topel   Eugene Garfield   Kevin Murphy

The 2005 Eugene Garfield Economic Impact on Medical and Health Research Award goes to Dr. Robert Topel and Dr. Kevin Murphy

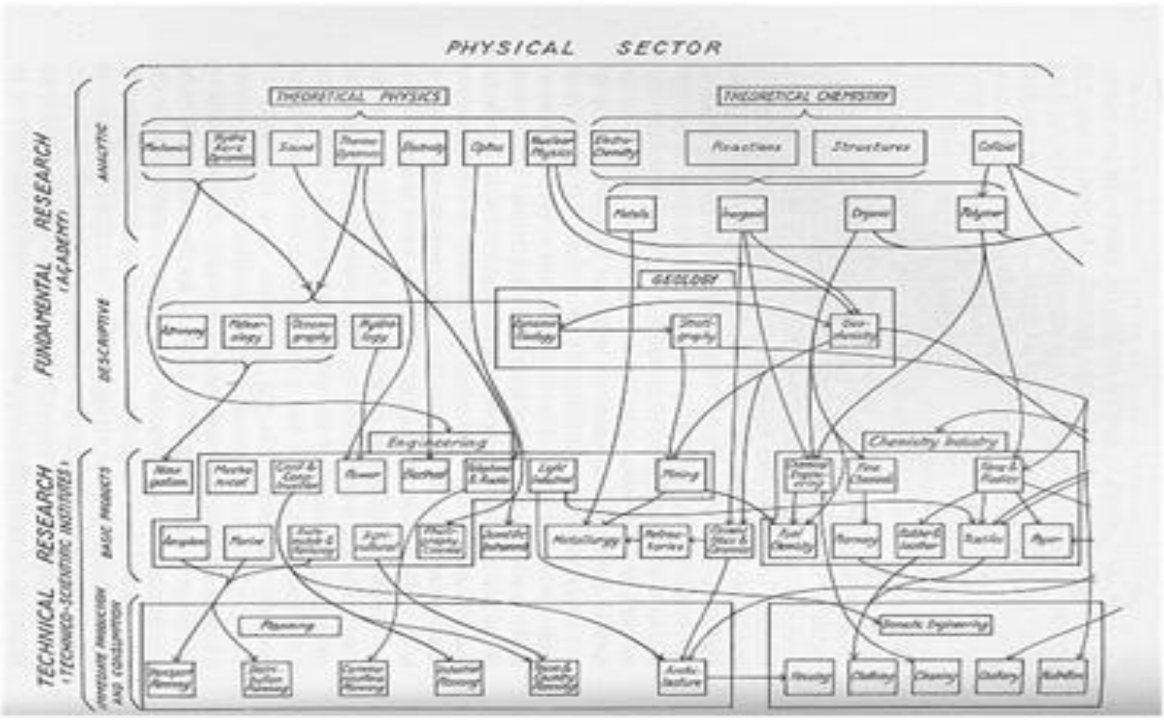
Dr. Eugene Garfield :<>: A humble Homage to a great information scientist.



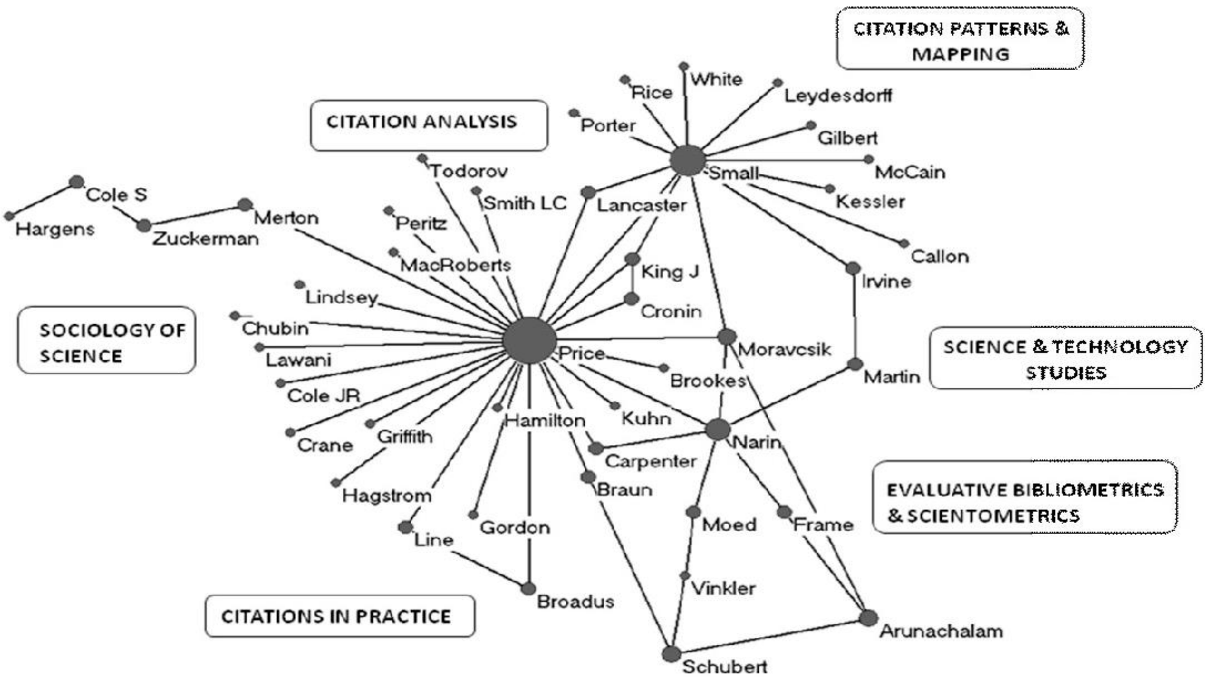
Eugene Garfield :<>: 60 Years of Invention and Innovation



Citation indexing and indexes



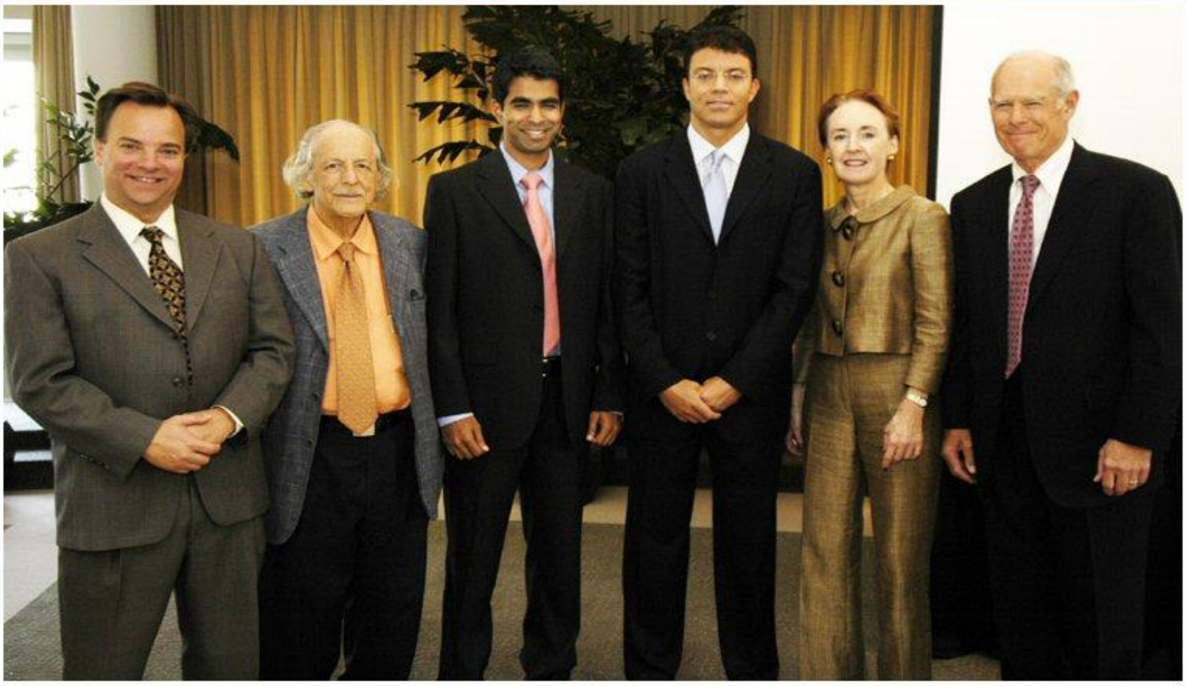
Citation Indexing Revisited: Garfield's Early Vision and its Implications for the Future.



The view from Garfield's shoulders: Tri-citation mapping of Eugene Garfield's citation image over three successive decades.

Eugene Garfield David Leonhardt Douglas Staiger Amitabh Chandra Mark McClellan Kevin White

The 2008 Eugene Garfield Economic Impact on Medical and Health Research Award was presented on October 14, 2008 in Washington D.C. to Amitabh Chandra, Ph.D. and Douglas O. Staiger, Ph.D.



Mark McClellan Eugene Garfield Anupam B. Jena Tomas Philipson Mary Woolley Hon. John Edward Porter

2007 Eugene Garfield Economic Impact on Medical and Health Research Award presented on October 9, 2007 in Washington D.C. to Anupam B. Jena, PhD, and Tomas J. Philipson, PhD, for

"Who Benefits from New Medical Technologies? Estimates of Consumer and Producer Surpluses for HIV/AIDS Drugs, published in Forum for Health Economics and Policy"

Biography

Prof Dr Eugene Garfield

Resource : http://www.garfield.library.upenn.edu/

"I think you're making history, Gene!" So said Nobel laureate and molecular biologist Joshua Lederberg to his friend Eugene Garfield in 1962. They were building the Science Citation Index (SCI), now the Clarivate Analytics Web of Science, with long-sought grants from US funding agencies. Today, we cannot imagine research without indexes that reveal how articles are cited. Garfield enabled an entire field: scientometrics, the quantitative study of science and technology.

* * * * *

Introduction

Garfield was born in 1925 in New York City as Eugene Eli Garfinkle, his mother being of Lithuanian Jewish ancestry. His parents were second generation immigrants living in East Bronx in New York City. He studied at the University of Colorado and University of California, Berkeley before getting a Bachelor of Science degree in chemistry from Columbia University in 1949. Garfield also received a degree in Library Science from Columbia University in 1953 He went on to do his PhD in the Department of Linguistics at the University of Pennsylvania, which he completed in 1961 for developing an algorithm for translating chemical nomenclature into chemical formulas. Garfield was survived by a wife, three sons, a daughter, two granddaughters, and two great-grandchildren. He was preceded by a daughter.

Education

Columbia University, B.S., Chemistry, 1949
Columbia University, M.S., Library Science, 1954
University of Pennsylvania, Ph.D., Structural Linguistics, 1961
Dissertation: An Algorithm for Translating Chemical Names to Molecular Formulas
Also see: Chemico-Linguistics: Computer Translation of Chemical Nomenclature, Nature, Vol:192, p.192, October 14,1961.

Career Overview

Dr. Garfield's career in scientific communication and information science began in 1951 when he joined the Welch Medical Indexing Project at Johns Hopkins University. The project was funded by the Army Medical Library, the predecessor of the National Library of Medicine. The goal of the project was to examine basic and applied problems of medical information retrieval, and the application of new methods to indexing the biomedical literature.1 A key objective was to improve the currency of the Current List of Medical Literature, through machine methods of compilation. This led to the present Index Medicus.

One of Garfield's contributions involved the revision of the subject heading authority list used for the Current List. More than 30,000 subject heading terms were then in use and available only on printed lists or index cards. The Welch Project transferred the data to punched cards for machine sorting. The lists they eventually produced became the first Subject Heading Authority List, the prototype of Medical Subject Headings, the authoritative list of indexing terms presently used by the Index Medicus staff. The Welch Project also laid the theoretical and practical foundations for other major information services of the National Library of Medicine--Medical Literature Analysis and Retrieval System (MEDLARS) and MEDLINE2

In addition, the Welch Project planted the seeds for several major advances in scientific communication and information science that have distinguished Dr. Garfield's career. They can be expressed as two basic and related themes: information discovery and information recovery.

Information discovery refers to how researchers stay current with the thousands of articles being published each week. In this regard, while still with the Welch Project, Garfield produced Contents in Advance, a current awareness publication that reproduced the contents pages of library documents and journals. This allowed users to browse a wide range of journals for relevant articles. It was the prototype of Current Contents, now published in seven discipline-specific editions. 3

Information recovery relates to how researchers locate relevant articles they know, or think, are out there somewhere in the flood of literature. Subject indexes, like Index Medicus, were the traditional means for information recovery. However, these indexes required substantial intellectual effort and subjective judgment by human indexers. The results were often confusing, duplicative, costly and quite late. At the Welch Project, Garfield became interested in using machines to automatically generate indexing terms that effectively describe a document's contents without human intervention. As a consequence of investigating the linguistic structure of review articles and traditional indexing methods, he was able to take advantage of a fortuitous encounter with legal citations. Eventually, this led to the development of the concept of citation indexes for scientific literature. By combining citation indexing with natural language indexing, he investigated precursors of today's Science Citation Index, including patent citation indexes.4 In those days, this was anathema to the traditional view of controlled Thesaurus based indexing or cataloging.

To pursue these interests at a professional level, Garfield earned a Master's degree in library science from Columbia University. After graduating in 1954, he became a consultant to the pharmaceutical industry. This eventually led to the formation of a private firm. In 1955, he produced a contents-page publication covering the social sciences and management literature. Bell Laboratories was the first major corporate client, contracting for 500 copies. By 1957, he began producing a similar service covering the literature of interest to pharmaceutical companies. Physicians and academic biomedical researchers soon discovered the new publication, Current Contents/Pharmaco-Medical & Life Sciences, and requested subscriptions.

In 1958, Garfield was contacted by Dr. Joshua Lederberg, who was interested in knowing what happened to the citation index Garfield had proposed in 1955 in Science. Their correspondence eventually led to a meeting with the NIH genetics study section and funding to produce and distribute a Genetics Citation Index. This included a multi-disciplinary index to the science literature of 1961. The NIH and NSF declined the opportunity to publish the latter index, so Garfield began regular publication of the Science Citation Index in 1964 through the Institute for Scientific Information, the name his firm assumed in 1960.

The SCI soon distinguished itself from other literature indexes and was recognized as a basic and fundamental innovation in scientific communication and information science. It was truly current while other traditional indexes were often several years behind the literature. The SCI was also comprehensive, indexing all types of source items--not just research articles and reviews, but also technical notes corrections and errata, letters, editorials, discussions, etc. The SCI was also multidisciplinary, covering virtually all disciplines and fields of science. Most important, the SCI uniquely indexed the references cited in the articles it indexed. This allowed users, for the first time, to take advantage of the associations and

connections that researchers themselves made through the references they cited in their papers.

From 1961 on, Garfield's career is marked by an extraordinary development of new information tools for researchers combined with constant enhancement of existing tools. The new tools include Index Chemicus, Current Chemical Reactions, new Current Contents editions covering clinical medicine, chemistry, physics, and other disciplines, Automatic Subject Citation Alert (a personalized selective dissemination of information service now called Research Alert), the Genuine Article (rapid document delivery), citation indexes for the social sciences (SSCI) as well as the arts and humanities (A&HCI), Index to Scientific & Technical Proceedings and Books, Index to Scientific Reviews, and others. Enhancement of existing products included expanded coverage of the literature, the addition of various author/publisher/address/directories as well as article abstracts, key words, and distribution in new media, such as magnetic tape, online, floppy diskette, and CD-ROM.

What is the impact of these new information tools on the medical practitioner and researcher? During the past three decades, as the volume of literature has been growing exponentially, Garfield's innovations have made it possible for researchers to cope with and keep up with articles directly relevant to their interests. His inventions have improved scientific communication by helping to limit wasteful duplication of prior research, reveal unexpected relationships between articles, identify significant improvements on earlier work, and draw attention to the important corrections or retractions of published research. The ISI services gave a new meaning to the terms "current awareness" and "navigating the literature." One reviewer called the SCI "systematic serendipity."5

Current Contents has become a vital and basic component of clinical research and the research laboratory. Users can browse the contents pages of hundreds of journals each week in *CC* and thereby keep up with the latest advances in their fields without having to spend hours in the library. Relevant articles can be obtained from the library, through ISI's document delivery service, or directly from the authors using *CC*'s address directories or via the Internet. *CC* is especially valued by smaller libraries, hospitals, and university departments with limited budgets for professional and research publications. For decades, *CC* was virtually the only source of current scientific information for researchers in the Third World, Russia, and former Soviet-bloc nations. With the advent of the WWW that has changed somewhat, but *CC* continues to be read widely in print and electronic form.

The SCI has become an important tool for navigating the scientific literature. The SCI can not only retrieve related papers that do not share title or keywords, but also provides an historical perspective on landmark work, permitting the user to see where this work has been cited subsequently. Based as it is on citation links, it was the precursor of Google and other search engines.

The SCI database has also provided an objective and quantitative basis for analyzing information flows in scientific communication. It has fostered the growth of the fields of bibliometrics, informetrics, and scientometrics. SCI data are used by information scientists, research administrators, and policy makers to reveal longitudinal trends in scientific communication, comparing nations, institutions, departments, research teams, or journals by their productivity and impact in various fields, disciplines, and specialties. The data are also used by sociologists and historians of science to explore important processes, phenomena, and developments in research. The data are also used by librarians for journal selection and "weeding", by editors to monitor their journal's relative impact and citation, and by publishers to help decide whether to launch new journals or retire existing ones.

Dr. Garfield continues to be active in scientific communication and information science. In 1986, he founded The Scientist, a bi-weekly newspaper for the research professional. It reports on news and developments relevant to the professional and practical interests of scientists, and provides a unique forum for the discussion of issues important both to the research community and society. Now published in magazine format, the full text is also available worldwide on the Internet and is augmented by daily science news reports.

In addition, Dr. Garfield maintains a heavy schedule of invited speeches and presentations before high-level medical, scientific, and information symposia and conferences. The topics have included science education, peer review, research evaluation, future trends in medical information and documentation, the economic and social impact of basic research, the value of animal experimentation, creativity in science, and other subjects. He has published over 1,000 weekly essays in Current Contents over the past twenty-five years and he has published and edited commentaries by the authors of over 5,000 Citation Classics.

In recent years, Garfield has taken up the development of algorithmic historiography, a theme he first pursued in 1964 when computer memories were still too primitive to take advantage of the limited structure of the SCI. Subsequently, he developed and patented the HistCite™ system which enables researchers and librarians to differentiate the most significant works on any given topic when conducting searches on the electronic version of the SCI, SSCI, and/or A&HCI. The output of this HistCite software is an historiographic chronological presentation of the key works and shows their interrelationships.

Professional Positions

1949-1950 Laboratory Chemist, Evans Research & Development Corp.
1950-1951 Research Chemist, Columbia University
1951-1953 Staff member, Welch Machine Indexing Project, Johns Hopkins University
1954-1960 President, Eugene Garfield Associates
1960-1992 President & CEO, Institute for Scientific Information
1986-2000 Publisher & Editor-in-Chief, The Scientist

1992-1992 Chairman, Institute for Scientific Information
1993- Chairman Emeritus,Institute for Scientific Information
1998-2000 President, ASIS&T (American Society for Information Science & Technology)
2001- President, The Scientist LLC.

Awards

1953- 54 Grolier Society Fellow, Columbia University
1966 Fellow, American Association for the Advancement of Science
1966 Fellow, Institute of Information Scientists
1975 Award of Merit, American Society of Information Science
1977 Herman Skolnick Award, American Chemical Society
1977 Hall of Fame Award, Information Industry Association
1978 American Society for Information Science Book Award for Best Information Science Book of 1977 (Essays of an Information Scientist, Vol: 1&2, 1962-1976
1980 Award, Chemical Notation Society
1983 Patterson-Crane Award, American Chemical Society
1983 John Price Wetherill Medal, Franklin Institute
1984 Derek J. de Solla Price Memorial Medal, Scientometrics
1986 John Scott Award, City of Philadelphia
1987 Distinguished Alumni Award, Columbia University, School of Library Service, New York
1988 Dr. honoris causa, Vrije University, Brussels Belgium
1990 Ph.D. (honorary), State University of New York, Albany
1991 Honorary Fellow, Society for Technical Communication
1991 Ph.D. (honorary), Thomas Jefferson University, Philadelphia
1993 Honorary Foreign Member, Institute of Marine Biology , Vladivostok, Russia
1993 Honorary Fellow, Medical Libraries Association
1993 M.D. (hon. caus.), University of Rome, Tor Vergata, Italy
1995 M.D. (hon. caus.), Charles University, Czech Republic
1997 Honorary Degree from Far Eastern University, Vladivostok, Russia
1997 Honorary Membership in the Russian Academy of Sciences, Vladivostok, Russia
1999 Avenue of Technology Award, Philadelphia, PA
2000 Professor Kaula Award for Library & Information Science, India
2001 Winifred Sewell Prize for Innovation in Information Technologies in Biomedical & Life Sciences Librarianship.
Awarded by Special Libraries Association Biomedical and Life Sciences Division
2004 Ph. D. (Honorary) Drexel University, Philadelphia, PA.
2004 Los Angeles Chapter -American Society for Information Science &Technology (ASIST)- Visionary Leader - Contributions to Information Science
2005 American Academy of Arts and Sciences, Fellow
2007 The Chemical Heritage Foundation - Richard J. Bolte, Sr. Award for Supporting Industries

2007 Honorary Degree from Real Academia de Medicina Del Distrito de Granada (Andalucia Oriental) Spain.
2007 American Philosophical Society, Philadelphia, PA. – Member

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Scientific & Professional Associations

American Academy of Arts and Sciences, Fellow
American Academy for Arts & Sciences
American Chemical Society
American Library Association
American Philosophical Society, Philadelphia, PA. - Member
American Society for Information Science & Technology (Past President)
American Association for the Advancement of Science (Fellow)
Authors Guild
Drug Information Association
Federation of American Scientists
History of Science Society
Institute of Electrical & Electronics Engineers
International Federation of Science Editors
Medical Library Association
National Association of Science Writers
New York Academy of Sciences
Society for Scholarly Publishers
Society for Social Studies of Science
Special Libraries Association

Editorial Board Membership

Annual Reviews, Inc., Board of Directors
International Federation of Science Editors
Scott Award Advisory Committee
Journal of Information Science
Rockefeller University Council
Scientometrics
University of Pennsylvania Library, Board of Overseers
Research! America
Temple University Health System, Inc. Board of Overseers

Please visit the web link to read his articles between 1952 and 2011

http://www.garfield.library.upenn.edu/pub.html

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Journal Impact Factor

Chapter 6 in the Book

"Publishing a Research Paper"

published by the Faculty of Management Studies
in 2012 [I Edition] & 2018 [II Edition]

2018 = Silver Jubilee Year

* * * * *

Highlights the evolution of Impact Factor [IF] from 1950s, and discusses various types of IF and their calculation. Offers some criticism about the uses and misuses of IF by various organizations.

Reproduced Here!

Chapter 6

M Vijayakumar

Highlights the evolution of Impact Factor [IF] from 1950s, and discusses various types of IF and their calculation. Of- fers some criticism about the uses and misuses of IF by vari- ous organizations.

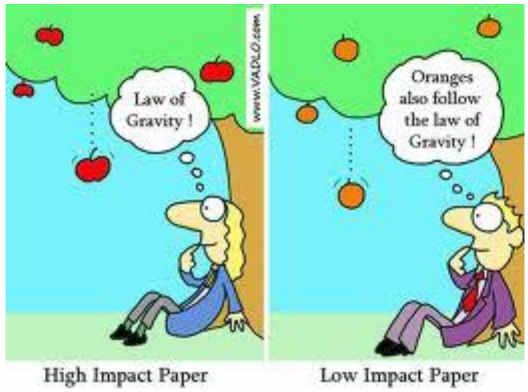
Silver Jubilee **2018** Publications

Journal Impact Factors

KEYWORDS

Chapter – 6 :: Journal Impact Factor

Impact factor
Journal impact factor
Journal Citation Report
Citation indexing
Aggregate impact factors
Manual indexing
Science Citation Index
Cited-only Journal
Self-citation



JOURNAL IMPACT FACTORS

Introduction

It has become mandatory for academic research scholars to publish a minimum number of research papers in peer-reviewed national or international reputed journals having a reasonable Impact Factor [IF] or also known as Journal Impact Factor [JIF]. Journal Impact Factor is from Journal Citation Report (JCR), a product of Thomson ISI (Institute for Scientific Information). JCR provides quantitative tools for evaluating journals. The impact factor is one of these; it is a measure of the frequency with which the "average article" in a journal has been cited in a given period of time.

Historical Background of Citation Indexing

The concept behind citation indexing is fundamentally simple. By recognizing that the value of information is determined by those who use it, what better way to measure the quality of the work than by measuring the impact it makes on the community at large. The widest possible population within the scholarly community (i.e. anyone who uses or cites the source material) determines the

influence or impact of the idea and its originator on our body of knowledge. Because of its simplicity, one tends to forget that citation indexing is actually a fairly recent form of information management and retrieval.

There were three factors that led to the development of citation indexing back in the 1950's. With the huge influx of government dollars into research and development following World War II, the research community naturally began to publicly document its findings through the accepted channel of published scientific journal literature. The subsequent burgeoning of the literature created a need for a method of indexing and retrieval that would be more cost effective and efficient than the then-current model of human indexing of materials for subject specific indices. While the subtle judgements made by subject specialists were valuable in giving depth to a subject index, manual indexing was both a more time consuming process and labor intensive. Its costs increased in proportion to the growth of material to be indexed. So the need for a better way of managing information was the first factor.

The second factor was the growing dissatisfaction with the capacity of subject indexing to meet the needs of the active researcher. At this point in time, a subject index could have excessive lag times in adding materials to the indexes of the time; months could pass before researchers in one field would learn of published findings in some other field that had relevance to their own study. Furthermore, there were limitations to the subject indexing in terms of retrieval. Terminology appropriate to one specific discipline would not necessarily have meaning to researchers in another, perhaps overlapping, discipline. At the same time, scientists were recognizing that they had to be aware of, if not completely familiar with, work in a number of different subject disciplines in order to be confident that they had properly grounded the research through an appropriate review of the literature.

Along with this need was the hope that automation might hold the answers, the third and final factor in the development of citation indexing. Computerization in the 1950s was far removed from the desktop environment of today, but there was tremendous excitement over potential benefits to be derived from the application of machines to the generation and compilation of data. The U.S. government hoped that automation could mitigate or

even eliminate completely the difficulties of manual indexing. A number of projects were launched by the United States with the intention of investigating these possibilities.


Dr Eugene Garfield

Dr. Eugene Garfield, founder and now Chairman Emeritus of ISI® (now Thomson Reuters), was deeply involved in the research relating to machine generated indexes in the mid-1950's and early 1960's. One of his earliest points of involvement was a project sponsored by the Armed Forces Medical Library (predecessor to our current National Library of Medicine). The Welch Medical Library Indexing project, as it was called, was to investigate the role of automation in the organization and retrieval of medical literature. Garfield grasped early on that review articles in the journal literature were heavily reliant on the bibliographic citations that referred the reader to the original published source for the notable idea or concept. By capturing those citations, Garfield believed, the researcher could immediately get a view of the approach taken by another scientist to support an idea or methodology based on the sources that the published writer had consulted and cited as pertinent in the bibliography. As retrieval terms, citations could function as well as keywords and descriptors that were thoughtfully assigned by a professional indexer.

In the early 1960s, Eugene Garfield and Associates developed two pilot projects that would test the viability and efficiency of citation indexing. The first project involved the creation of a database that would index the citations of 5,000 chemical patents held by two private pharmaceutical companies. The referenced citations in this instance were to prior patents, the documentation sources that the government patent examiners were using to support a decision to grant or deny a patent. The connections that the patent citation index made were then analyzed with two comparable classifications and indexing systems that were currently being used by the participants. Based on this investigation and analysis, the project sponsors determined that

citation indexing permitted the retrieval of relevant literature across arbitrary classifications in a way that subject- oriented indexing could not.

While, at the time of the project's completion, the government sponsors chose not to subsidize the development of a national citation database, Eugene Garfield was encouraged to move ahead with the private publication of his multidisciplinary citation index as the first edition of the *Science Citation Index* (SCI). Available for purchase since 1963, the *SCI* then and now represents the most comprehensive citation index to the scientific journal literature. Today, the Web-based version of that index covers 5,600 journals across more than 150 scientific disciplines.

Garfield's achievement lay in establishing the utility and objectivity of a citation index in pulling up related papers in published literature that at first glance might not have seemed pertinent to the researcher's inquiry. Today, it is considered to be one of the most reliable of resources in tracing the development of an idea across the multitude of disciplines that are part of our body of scientific knowledge.

"Issue settled. JBC has it higher!"

What is Impact Factor [IF]?

The *JCR* provides quantitative tools for ranking, evaluating, categorizing, and comparing journals. The impact factor is one of these; it is a measure of the frequency with which the "average article" in a journal has been cited in a particular year or period. The annual impact factor is a ratio between citations and recent citable items published. Thus, the impact factor of a journal is calculated by dividing the number of current year citations to the source items published in that journal during the previous two years. The journal Impact Factor is the average number of times articles from the journal published in the past two years have been cited in the JCR year. The Impact Factor is calculated by dividing the number of citations in the JCR year by the total number of articles published in the two previous years. An Impact Factor of

1.0 means that, *on average*, the articles published one or two year ago has been cited one time. An Impact Factor of 2.5 means that, on average, the articles published one or two year ago have been cited two and a half times. Citing articles may be from the same journal; most citing articles are from different journals. The impact factor is useful in clarifying the significance of absolute (or total) citation frequencies. It eliminates some of the bias of such counts which favor large journals over small ones, or frequently issued journals over less frequently issued ones, and of older journals over newer ones. Particularly in the latter case such journals have a larger citable body of literature than smaller or younger journals. All things being equal, the larger the number of previously published articles, the more often a journal will be cited.

Example [A]:

Impact Factor [IF] is calculated as follows:

No. of times articles published in 2010 & 2011 were cited in indexed Journals during the year 2012 = A

No. of articles, reviews, or notes published in 2010 & 2011 = B

Impact Factor for the year 2012 = A/B
If A = 150, B = 125, then IF [A/B] = 150 / 125 = 1.2

Example [B]:

Impact Factor [IF] for 5 years is calculated as follows:

No. of times articles published in 2007, 2008, 2009, 2010 & 2011 [ie, last 5 years] were cited in indexed Journals during the year 2012 = A

No. of articles, reviews, or notes published in these 5 years as above = B

Impact Factor for the year 2012 = A/B

If A = 750, B = 625, then IF [A/B] = 750 / 625 = 1.2

[**Note**: The 5-year Impact Factor is available only in JCR 2007 and subsequent years.]

Aggregate Impact Factors
This is somewhat a type of fine-tuned Impact Factor, ie., the aggregate Impact Factor is meant for a subject category. It is calculated in the same way as the Impact Factor of a Journal. But here, the number of citations to all journals in a particular category [for example, market research] and the number of articles from all these journals in that category are taken into account. An aggregate Impact Factor of 2.0 means that that, *on average*, the articles in a particular subject category [ie. market research] published one or two years ago have been cited twice.

Example [C]:

Aggregate Impact Factor [IF] is calculated as follows:

No. of times articles published in 2010 & 2011 were cited in indexed Journals in a particular category [market research] during the year 2012 = A

No. of articles, reviews, or notes published in these Journals for 2 years as above = B

Aggregate Impact Factor for the year 2012 = A/B

If A = 2250, B = 1950, then Aggregate IF [A/B] = 2250 / 1950 = 1.15

Cited-only Journals in the JCR

Some of the journals listed in the *JCR* are not citing journals, but are cited-only journals. This is significant when comparing journals by impact factor because the self-citations from a cited-only journal are not included in its impact factor calculation. Self-citations often represent about 13% of the citations that a journal receives. Users can identify cited-only journals by checking the *JCR* Citing Journal Listing. Furthermore, users can establish analogous impact factors, (excluding self-citations), for the journals they are evaluating using the data given in the Citing Journal Listing.

Calculation of Impact Factor revised to exclude self-citations:

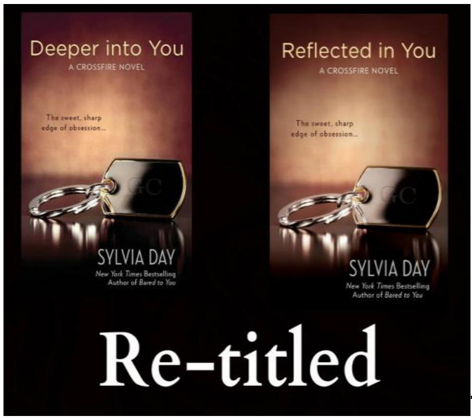
A = citations in 2012 to articles published in 2010 & 2011
B = 2012 self-citations to articles published in 2010 & 2011
C = A – B = Total citations excluding self-citations to recent articles
D = No. of artices published in 2010 & 2011
E = Revised Impact Factor = C / D
[Earlier Impact Factor = A / D]

Example [D]:

Calculation of Impact Factors without self-citations.

Name of the Journals	**JCR Impact Factor [A / D]**	**Cites in 2012 to 2010 & 2011 Articles A**	**Self-cites in 2012 to 2010 & 2011 Articles B**	**Minus Self-Cites C = (A-B)**	**Articles Published 1990-91 D**	**Revised Impact Factor E = C/D**
Journal I	**1.40**	525	-	525	375	**1.40**
Journal II	**1.48**	775	55	720	525	**1.37**
Journal III	**1.23**	1075	95	980	875	**1.12**
Journal IV	**1.15**	2250	165	2085	1950	**1.07**
Journal V	**1.10**	675	85	590	615	**0.96**
Journal VI	**1.20**	1975	215	1760	1650	**1.07**

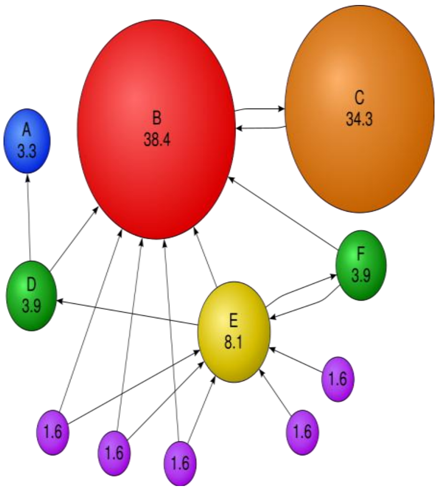
A comparison of JCR Impact Factors and Revised Impact Factors of these six sample Journals highlights the significant difference and tell-tales the fine-tuning of revised IF. These values alone will be considered when self-citations are excluded.



Title Change

A user's knowledge of the content and history of the journal studied is very important for appropriate interpretation of impact factors. Situations such as those mentioned above and others such as title change are very important, and often misunderstood.

A title change affects the impact factor for two years after the change is made. The old and new titles are not unified unless the titles are in the same position alphabetically. In the first year after the title change, the impact is not available for the new title unless the data for old and new can be unified. In the second year, the impact factor is split. The new title may rank lower than expected and the old title may rank higher than expected because only one year of source data is included in its calculation. Title changes for the current year and the previous year are listed in the *JCR* guide.



Calculation of Unified 2012 Impact Factor for Title Change

P = 2012 citations to articles published in 2010 & 2011 [A1 + A2]

P1 = for New Title
P2 = for Superseded Title

Q = No. of articles published in 2010 & 2011 [B1 + B2]

Q1 = for New Title
Q2 = for Superseded Title

R = Unified Impact Factor = P / Q

R1 = P1 / Q1 = JCR Factor for the New Title
R2 = P2 / Q2 = JCR Factor for the Superseded Title

Applications of Impact Factors

There have been many innovative applications of journal impact factors. The most common involve market research for publishers and others. But, primarily, *JCR* provides librarians, academic research scholars as well as professional researchers with a tool for the management of library journal collections. In market research, the impact factor provides quantitative evidence for editors and publishers for positioning their journals in relation to the competition—especially others in the same subject category, in a vertical rather than a horizontal or intradisciplinary comparison. *JCR* data may also serve advertisers interested in evaluating the potential of a specific journal.

Perhaps the most important and recent use of impact is in the process of academic evaluation. The impact factor can be used to provide a gross approximation of the prestige of journals in which individuals have been published. This is best done in conjunction with other considerations such as peer review, productivity, and subject specialty citation rates. As a tool for management of library journal collections, the impact factor supplies the library administrator with information about journals already in the collection and journals under consideration for acquisition. These data must also be combined with cost and circulation data to make rational decisions about purchases of journals.

The impact factor can be useful in all of these applications, provided the data are used sensibly. It is important to note that subjective methods can be used in evaluating journals as, for example, by interviews or questionnaires. In general, there is good agreement on the relative value of journals in the appropriate categories. However, the *JCR* makes possible the realization that many journals do not fit easily into established categories. Often, the only differentiation possible between two or three small journals of average impact is price or subjective judgments such as peer review.

Conclusion

Though the impact factor is found to be a very useful tool by academic fraternity for evaluation of journals, but it must be used very cautiously and discreetly. Considerations include the amount of review or other types of material published in a journal, variations between disciplines, and item-by-item impact. But, for junior research scholars, the Impact Factor of a Journal may be very useful in their research study.

Following Sources are duly acknowledged:

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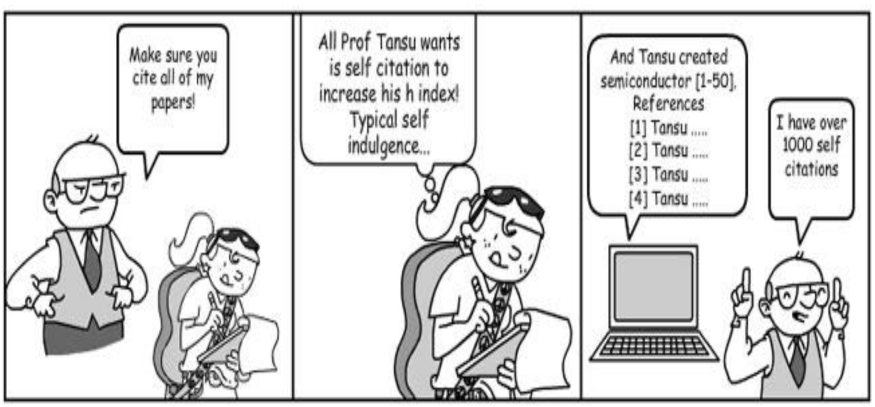

“Impact factors, are useful in establishing the influence journals have within the literature of a discipline.”

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Citation Indexes

KEYWORDS

Chapter – 10 :: Citation Indexes

Citation indexes
Journal impact
Evolution
Structure of citation indexes
Science Citation Index
Scientific journal literature
Obscure references
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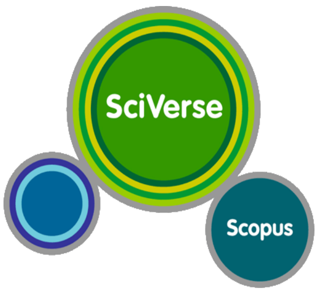
Citation Indexes



Introduction

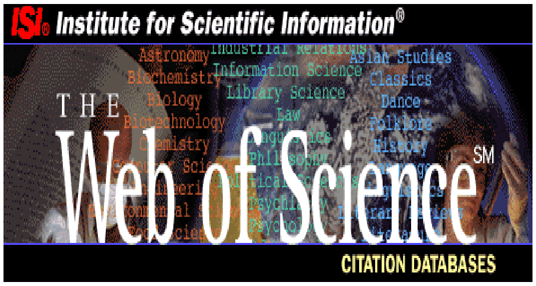
Usage of research work of researcher always pays importance and value to the author and also to the work. Work in the form of article, patents and notes in the subject get its impact when it got cited in the literature of importance. Trace the citations in different publications involves constant perusal, which is rather difficult for an author. The mapping of citations in a subject and also in allied subjects is really very intricate work and the whole idea emerged as early as tool to visualize citation relationships and understand the meaning of a cited reference search in web of knowledge. The concept behind citation indexing is fundamentally simple. By recognizing that the value of information is determined by those who use it, what better way to measure the quality of the work than by measuring the impact it makes on the community at large. The widest possible population within the scholarly community (i.e. anyone who uses or cites the source material) determines the influence or impact of the idea and its originator on our body of knowledge. Because of its simplicity, one tends to forget that citation indexing is actually a fairly recent form of information management and retrieval. Citation indexes track references that authors put in the bibliographies of published papers. They provide a way to search for and analyze the literature in a way not possible through simple keyword/topical searching. It also enables

users to gather data on the "impact" of journals, as well as assessing particular areas of research activity and publication.

What are Citation Indexes?

There were three factors that led to the development of citation indexing back in the 1950's. With the huge influx of government dollars into research and development following World War II, the research community naturally began to publicly document its findings through the accepted channel of published scientific journal literature. The subsequent burgeoning of the literature created a need for a method of indexing and retrieval that would be more cost effective and efficient than the then-current model of human indexing of materials for subject specific indices. While the subtle judgements made by subject specialists were valuable in giving depth to a subject index, manual indexing was both a more time consuming process and labor intensive. Its costs increased in proportion to the growth of material to be indexed. So the need for a better way of managing information was the first factor. The second factor was the growing dissatisfaction with the capacity of subject indexing to meet the needs of the active researcher. At this point in time, a subject index could have excessive lag times in adding materials to the indexes of the time; months could pass before researchers in one field would learn of published findings in some other field that had relevance to their own study. Furthermore, there were limitations to the subject indexing in terms of retrieval. Terminology appropriate to one specific discipline would not necessarily have meaning to researchers in another, perhaps overlapping, discipline. At the same time, scientists were recognizing that they had to be aware of, if not completely familiar with, work in a number of different subject disciplines in order to be confident that they had properly grounded the research through an appropriate review of the literature. The third and final factor in the development of citation indexing is the hope that automation might be the key to the future challenges. Computerization in the 1950s was far removed from the desktop environment of today, but there was tremendous excitement over potential benefits to be derived from the

application of machines to the generation and compilation of data. A number of projects were launched by the United States with the intention of investigating these possibilities.



Evolution of Citation Index

Dr. Eugene Garfield, founder and now Chairman Emeritus of ISI (now Thomson Reuters), [*also considered as Grandfather of Google*] was deeply involved in the research relating to machine generated indexes in the mid-1950's and early 1960's. One of his earliest points of involvement was a project sponsored by the Armed Forces Medical Library (predecessor to our current National Library of Medicine). The Welch Medical Library Indexing project, as it was called, was to investigate the role of automation in the organization and retrieval of medical literature. The hope was that the problems associated with subjective human judgement in selection of descriptors and indexing terms could be eliminated. By removing the human element, one might thereby increase the speed with which information was incorporated in to the indexes. It might also increase the cost-effectiveness of the indexes. Garfield grasped early on that review articles in the journal literature were heavily reliant on the bibliographic citations that referred the reader to the original published source for the notable idea or concept. By capturing those citations, Garfield believed, the researcher could immediately get a view of the approach taken by another scientist to support an idea or methodology based on the sources that the published writer had consulted and cited as pertinent in the bibliography. As retrieval terms, citations could function as well as keywords and descriptors that were thoughtfully assigned by a professional indexer.

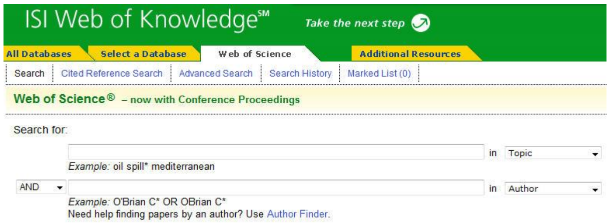
In the early 1960s, Eugene Garfield and Associates developed two pilot projects that would test the viability and efficiency of citation indexing. The first project involved the creation of a database that would index the citations of 5,000 chemical patents held by two private pharmaceutical companies. The referenced citations in this instance were to prior patents, the documentation sources that the government patent examiners were using to support a decision to grant or deny a patent. The connections that the patent citation index made were then analyzed with two comparable classifications and indexing systems that were currently being used by the participants. Based on this investigation and analysis, the project sponsors determined that citation indexing permitted the retrieval of relevant literature across arbitrary classifications in a way that subject- oriented indexing could not.

A second pilot project in 1962 involved Garfield's recently incorporated enterprise, the Institute for Scientific Information (now Thomson Reuters), with the United States National Institutes of Health in building an index to the published literature on genetics. This project was far more complex in nature than the patents index. Three databases were built to cover the literature over 1 year, 5 years and 14 years with a varying number of source publications indexed in each. While this project was to test the feasibility and utility of a narrow, discipline-oriented citation index, at completion, it was concluded that the database with the *most broadly based set of source publications* formed the most comprehensive and useful guide to the published literature in the field of genetics. The database for the single-year term had drawn not just on journals that were primarily devoted to the field of genetics research but had drawn as well from a large pool of journals that published genetics papers on a more peripheral or occasional basis. Additionally, while the automated system required a certain level of effort in standardizing the entries from a wide variety of published materials, the project demonstrated the cost-effectiveness of citation indexing as opposed to the expense of traditional subject indexing processes.

While, at the time of the project's completion, the government sponsors chose not to subsidize the development of a national citation database, Eugene Garfield was encouraged to move ahead with the private publication of his multidisciplinary citation index as the first edition of the *Science Citation Index* (SCI).

Available for purchase since 1963, the *SCI* then and now represents the most comprehensive citation index to the scientific journal literature. Today, the Web-based version of that index covers 5,600 journals across more than 150 scientific disciplines.

Garfield's achievement lay in establishing the utility and objectivity of a citation index in pulling up related papers in published literature that at first glance might not have seemed pertinent to the researcher's inquiry. Today, it is considered to be one of the most reliable of resources in tracing the development of an idea across the multitude of disciplines that are part of our body of scientific knowledge.



Structure of Citation Index

The layout of citation index includes various approaches which researchers need to find out the literature and its impact. It has different index components such as Citation, Source, Subject, organization and geographic distributions of literature in the research field. The most analytical approach in the literature includes the journal citation reports giving details about impact factor of publications in its various formats. Citation components are discussed as follows:

Citation Index

Provides access to the network of the articles in the general form. It alphabetically lists the names of all the first authors whose works were cited during the period covered, and tells when and where those works were originally published. Citation index basically consists of authored cited items, anonymous cited items and patents cited.

Citation Index (Author)

Cited Articles are arranged by Author surname alphabetically and first author of a cited item appears only once in the citation index. Other bibliographic information of a cited item includes Year, Journal Title Abbreviation, Vol, and Start Page followed by bibliographic information of citing item includes the Source Author

name, Journal Title, Vol, Page, Year and Code type of the Source item (Review, Note, Letter, Editorial, Meeting etc). Where two or more cited items are listed without interruption by any citing source item it means that they were each cited by the author(s) of the citing source item(s) that follow.

Functions of Citation Indexes

[a] Find papers that cite earlier papers

Citation indexing is a way to look forward in the literature from the starting point of a particular paper or group of papers. This is a different and complementary approach to ordinary word-based literature searching, which looks backward in the literature from the present time. For example, if you have an excellent paper on a particular topic that was published in 1992, you can use Science Citation Index (via Web of Science) to find papers published after 1992 that cited that paper. Citation implies a direct subject relationship between the papers. So, by searching for later papers citing your known paper, you can find more documents on the same or similar topic without using any keywords or subject terms.

[b] Find out how many times my papers have been cited. Determine h-index

The h-index is a measure of "citedness" as a surrogate for productivity and impact. It is the number of articles h in a group of publications N that have received h or more citations. For example, an h-index of 20 means that there are 20 items in the selected group N that have received 20 or more citations. It is like a median and useful because it discounts the disproportionate weight of highly cited and uncited papers that would skew a mean. However, the h-index will vary considerably depending on a person's number of credited publications and the length of time they've been active: older and more prolific authors will usually have higher h-indexes than younger or less prolific authors. If you want to compare your h-index to someone else's, you need to use the same methodology to calculate them and then normalize the values by dividing them by a second factor, e.g. years since PhD. The standard caveats apply when using h-indexes in personnel and funding decisions.

[c] Determine which are the "best" journals in my field

Citation data have long been used to rank journals within particular subject areas, usually based on the ISI **Impact Factor.** The impact factor is a numerical ratio of the total number of citations a journal receives in Web of Science Source Journals in one year to the total number of "citable" articles it published in the previous two years. It is useful to see how journals perform in relation to others in the same subject area. It is

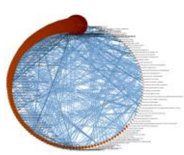
not useful in comparing journals across subject areas, and the number taken out of this context is essentially meaningless. Impact factor can also vary based on the number and types of articles a journal publishes. Review articles tend to be more heavily cited than full papers or communications, so journals and annuals that publish mostly reviews will often have high impact factors. Journals that publish only a few articles in a given year may also have disproportionately high impact factors. Similarly, one very highly cited paper can skew a journal's impact factor.

[d] Verify old and obscure references

Sometimes you'll run across a mysterious reference, and you won't be able to determine what it's referring to. By searching that reference as a "cited reference" in Web of Science, you may find other, more complete citations that might solve the mystery. It doesn't matter how old the mystery item is -- if someone has cited it will show up in the Citation Index.

Conclusion

Citation Index is a complete solution to scientific literature search and at present it is available online with data search and has a wider acceptance through Web of Science. It is a bibliographic database which has a software package that calculates the impact factor of the selected journals. Online version enables searchers to locate recent articles which cite earlier published work and saves time and money by eliminating the need to acquire and search discipline-oriented indexes. Citation index for specific language is needed to be constructed. Evaluation of the work of any scientist and of the journals covering specific areas of science is possible through Citation Index by distilling the credits with the established norms. Citation index needs to be upgraded from time-to time by creating and designing it for specific subject using latest technology and manual efforts.



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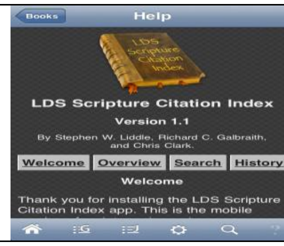

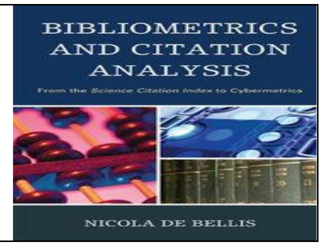

Quotation, n: The act of repeating erroneously the words of another.
Ambrose Bierce

The Eugene Garfield Doctoral Dissertation Competition

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* * * * *

The award recognizes dissertations that deal with substantive issues related to library and information science. Applicants may be from within or outside LIS programs.

One outstanding dissertation will be selected. The winner will receive $500, plus conference registration at the ALISE annual meeting, and personal membership in ALISE. The winner of the Dissertation Competition will present a summary of their work at the ALISE annual meeting.

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Dissertations will be judged on the following criteria:

- Significance of the research problem to the overall LIS field.
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- Conduct of study (i.e., application of methods of data collection).
- Analysis and presentation of the data (i.e., quality of analysis, logic of findings).
- Appropriateness of conclusions.
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Applicants need to submit their applications. The members of ALISE Eugene Garfield Doctoral Dissertation Competition Committee will judge a 30-page summary of the dissertation (i.e. problem statement, brief literature review, research questions, methodology, findings, interpretation, implications, and conclusions). In cases where the

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Those who completed their dissertation between March 1, 2022 and February 28, 2023 are eligible for the 2023 competition.

Submission Requirements

Your submission must include:

- A 200-word-abstract of the dissertation
- A 30-page summary of the dissertation (i.e. problem statement, brief literature review, research questions, methodology, findings, interpretation, implications, and conclusions) completed between March 1, 2022 and February 28, 2023
- Proof of university acceptance; we accept the following evidence as proof of university acceptance: a university transcript facsimile, official or unofficial, showing doctoral degree awarded or a letter from the advisor indicating university acceptance within the timeframe

Submission Process

All submissions must be completed through the ALISE 2023 submission system. *First-time users will be required to create an account (separate from your www.alise.org account). Once created, return to the ALISE '23 submission page to log in. Once logged in, select 'Enter as an author'. Select the relevant track for your submission, ensuring you review all requirements prior to completing your submission.

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Chair may recommend additional committee members if warranted by number of submissions.

Board Liaison

Lisa O'Connor, University of North Carolina Greensboro

Previous Winners

2022 - Deborah Garwood, Drexel University, *To Our Health: A Case Study of Archivists' Information Work and Information Practices at History of Medicine Collections in Philadelphia*

2021 - Darra Hofman, San Jose State University, *Between Knowing and Not Knowing: Privacy, Transparency, and Digital Records*

2020 - Eva Revitt, University of Alberta, *The Academic Librarian as the Subaltern: An Institutional Ethnography of a Feminized Profession.*

2019 - Timothy Gorichanaz, Drexel University, for *Understanding Self-Documentation*

2018 - Rachel Clark, Syracuse University, for *It's Not Rocket Library Science: Design Epistemology and American Librarianship*

2017 - Devon Greyson, University of British Columbia, for *Health-Related Information Practices and the Experiences of Young Parents*

2016 - Angela Pollak, University of Western Ontario, for *Words to Live By: How Experience Shapes Our Information World at Work, Play, and in Everyday Life*

2015 - Kyong Eun Oh, Rutgers University, for *The Process of Organizing Personal information*

2014 - Youngseek Kim, University of Kentucky, for *Institutional and Individual Influence on Scientists' Data Sharing Behavior*

2013 - Kimberly Anderson, University of California, Los Angeles, for *Appraisal Learning Networks: How University Archivists Learn to Appraise through Social Interaction*

Michelle Caswell, University of Wisconsim - Madison, for *Archiving the Unspeakable: Silence and Voice in Khmer Rouge Mug Shots*

2012 - Eric Matthew Meyers, University of Washington, for *The Nature and Impact of Information Problem Solving in the Middle School Classroom*

2011 - Shari Ann Lee, St. John's University - Queens, for *Teen Space: Designed for Whom?* and Cassidy Sugimoto, Indiana University - Bloomington, for *Mentoring,*

Collaboration, and Interdisciplinary: An Evaluation of the Scholarly Development of Information and Library Science Doctoral Students

2010 - Charles Kamau Maina, University of Western Ontario, for *The Traditional Knowledge Protection Debate: Identifying and Listening to the Voices of Traditional Knowledge Holders*

Honorable Mention: Tiffany Veinot, University of Western Ontario, for *Social Capital and HIV/AIDS Information Help Exchange Networks in Rural Canada*

2009 - Xiaojun Yuan, Rutgers University, for *Supporting Multiple Information-Seeking Strategies in a Single System Framework*

2008 - Kara Anne Reuter, University of Maryland, for *Children Selecting Books in a Library: Extending Models of Information Behavior to a Recreational Setting*

2007 - Kate Williams, Dominican University, for *Social Networks, Social Capital, and the Use of Information and Communications Technology in Socially Excluded Communities: A Study of Community Groups in Manchester England*

2006 - Diane Kelly, University of North Carolina Chapel Hill, for *Understanding Implicit Feedback and Documents Preference: A Naturalistic User Study*

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Eugene Garfield Doctoral Dissertation

Scholarship

Please visit the web link

https://www.issi-society.org/awards/eugene-garfield-doctoral-dissertation-award/

Nature of the award. The Eugene Garfield Doctoral Dissertation Scholarship consists of an award of EUR 3,000 (donated by the Eugene Garfield Foundation) to cover any research related expenses of the grant recipient, contingent upon the recipient's attending ISSI2021, the next ISSI biennial conference. This conference will be held online, July 12-15, 2021.

Purpose of the award. The purpose of this scholarship is to foster research in informetrics, including bibliometrics, scientometrics, webmetrics and altmetrics by encouraging and assisting doctoral students in the field with their dissertation research.

Eligibility. The scholarship recipient must meet the following qualifications: (a) Be an active doctoral candidate pursuing research using informetric, bibliometric, scientometric, webmetric or altmetric methodology in a degree-granting institution; (b) Have a doctoral dissertation proposal accepted by the institution or by their dissertation advisor. Clarification: an active doctoral student is someone who has not yet obtained the doctoral degree at the moment he/she receives the award. Moreover, the applicant need not be a member of ISSI to be considered for this scholarship.

Administration. The award is sponsored by the Eugene Garfield Foundation with the cooperation of the Chemical Heritage Foundation, and is administered by the Board of the International Society for Scientometrics and Informetrics (ISSI).

Nominations. Submission should include the following: (a) The doctoral research proposal, including a description of the research, methodology, and

significance, 5 pages or less in length, double-spaced, and in English; (b) A copy of the paper submitted for presentation at the ISSI Conference; (c) A cover letter from the dissertation advisor endorsing the proposal and confirming that the contents of this proposal are accepted by the institute, or at least by the advisor; (d) An up-to-date curriculum vitae.

Submission instructions and deadline. Submissions should be emailed to Professor Birger Larsen at egdds.award@gmail.com by April 10, 2021.

Selection. All the submitted material, in particular the doctoral research proposal, and the paper submitted to this year's ISSI conference, will be taken into consideration in the evaluation. The evaluation committee will consist of a subcommittee of no more than four individuals, with one ISSI Board member.

Conference presentation. The recipient of the award will be given the opportunity to present his/her work either during a normal session (if his/her paper has been accepted for presentation), either as a special lecture on the same level as research in progress. This presentation will be referred to as the special Eugene Garfield Doctoral Dissertation Scholarship Lecture.

Some further clarifications: (a) The candidate must have the intention to attend the conference, as shown by a submitted paper; (b) The awardee is free to use the award money as he/she pleases. The award does not have to (but of course may) be used for registration or travelling to the conference; (c) The awardee is not automatically entitled to an (extra) travel grant from the conference organizers or from ISSI. Of course he/she may apply for such a grant (if such grants are made available by the organizers) like any other conference participant.

Winners:

Year	Winners / Runners
2021	Winner - Joshua Eykens, University of Antwerp (Belgium)
2019	Winner - Jiangen He, Drexel University (USA) Runner ups - Adèle Paul-Hus, Université de Montréal (Canada) and Zhichao Fang, CWTS Leiden (The Netherlands)
2017	Winner - Philippe Mongeon, Université de Montréal (Canada)

2015	Winner - Cathelijn J. F. Waaijer, CWTS Leiden (The Netherlands) Runner up - Zohreh Zahedi, CWTS (The Netherlands)
2013	Winner - Ehsan Mohammadi, University of Wolverhampton (UK)
2011	Winner - Stefanie Haustein, Forschungszentrum Jülich (Germany) Runner ups - Raf Guns, University of Antwerp (Belgium) and Björn Hammarfelt, Uppsala University (Sweden)
2009	Winner - Vincent Larivière - McGill University (Canada)
2007	Winner - Sonia Vasconcelos - Universidade Federal do Rio de Janeiro (UFRJ) (Brazil)
2005	Winner - Kayvan Kousha – University of Tehran (Iran)

Eugene Garfield Award for

Innovation in Citation Analysis

Established in 2017, this international award honors Eugene Garfield's legacy of generosity and support for scientists around the world. It recognizes early career researchers in scientometrics developing innovative techniques in citation analysis that deepen our understanding of scientific and scholarly communication.

Overview

As a pioneer in automated indexing and retrieval of information since 1955, Eugene Garfield (1925-2017) developed citation databases for science that changed how researchers search and assess the scholarly literature. Now part of Clarivate, the Web of Science indexes the contents and the citation network of the world's premier scientific and scholarly journals and proceedings and is the direct descendant of the Science Citation Index, which Garfield introduced in 1964.

As the founder of the Institute for Scientific Information (ISI), Dr. Eugene Garfield had many interests related to information science and technology the use of citations (cited references) in information retrieval, research assessment, and the study of the science of science, being key themes of his work. In 2017 Clarivate established an award in his name to honor his legacy by recognizing excellence in the advancement our understanding of research impact and innovation.

Dr. Garfield's vision of supporting innovation in bibliometrics was unprecedented. He gave special attention to providing support to scientists from around the globe to research and develop new analytical methodologies, indicators, and metrics to advance our understanding of the scientific endeavor.

Eligibility

To be eligible, you must be an early career researcher: No more than PhD + 10 years at the time of application.

The award will be granted to the applicant who demonstrates an innovative approach to scientific evaluation that will utilize either citation analysis or a combination of citation analysis and additional data sources to address any research areas that include, but are not limited, to:

- Research integrity:
  - Methods to track, analyze and account for corrected and retracted articles in evaluations
  - Methods and frameworks to tackle the reproducibility crisis
- Research evaluation:
  - Novel indicators of institutional and researcher impact
  - Novel indicators to track the societal impact of research
- Diversity & Inclusion:
  - Methods to track diversity and inclusion
  - Methods to map and track diverse teams
  - Methods to analyze the output and impact of diverse teams (on national and international levels)
  - Developing diversity and inclusion indicators
- Sustainability and innovation:
  - New methods to apply Sustainability Development Goals (SDGs) in research evaluation
  - New methods to track innovation through publications
  - Methods to identify emerging topics

About the Award

The award amount is $25k USD, paid in a single instalment.

In addition to the award, Clarivate provides the successful applicant with research access to a selection of the Web of Science data.

A review committee evaluates applications for novelty, utility and innovation, and announces the winner publicly in September/October each year.

Note: Please visit the web link

https://clarivate.com/webofsciencegroup/eugene-garfield-award-for-innovation-in-citation-analysis-2022/

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Eugene Garfield Research Fellowship

The Eugene Garfield Research Fellowship promotes and supports research in the discoverability and dissemination of information by incorporating the history of our profession. The fellowship was endowed by Eugene Garfield, AHIP, FMLA (1926-2017), founder and former chair of the Institute for Scientific Information (ISI). Garfield is known for his innumerable and significant contributions to the practice of medical librarianship, including the creation of the Science Citation Index and the Journal Impact Factor. The fellowship, established in 2013, was intended to stimulate research into the history of information science in the medical or health sciences, recognizing that rediscovery, interpretation, and understanding of the rich history in this key knowledge area helps practitioners and researchers interpret the present and prepare for the future. In 2019, the fellowship was modified to expand on the concept of making information more discoverable, in honor of Dr. Garfield's work.

The fellowship recipient or research collaboration group receives a certificate at the Medical Library Association's annual conference and a stipend of $5,000 after the annual conference to be used for research-related purposes regarding the discoverability in information science. The research may incorporate topics such as informatics, expert searching, systematic reviews, critical appraisal, scholarly communication, data science, reference management, or other areas focused on ways to improve discoverability and dissemination of information.

Do you want to present the best application possible and improve your chances of receiving this fellowship?

- Take advantage of the Research Mentoring Program which offers research assistance and advice to all members of MLA.
- See MLA's Getting Started with Research webinar.
- Review the MLA Research Imperative.

Terms

- Garfield Fellowships are funded through a competitive annual grant program with applications due by **November 15** of each year.
- The award is not restricted to disbursement in a single year and funding may be disbursed over a period of up to two years depending on the needs of the research fellow or research collaboration group.
- The award may be used to supplement or extend other awards, including other private or government-supported fellowships, but is not contingent on receiving other awards.
- The successful applicant/group must submit an annual progress report to the MLA.

- Research should normally lead to a publishable manuscript with the intention of submission to a peer-reviewed publication including the *Journal of the Medical Library Association* or other appropriate publication.

Grant Funds

The Garfield Research Fellow receives an unrestricted grant that is awarded to the applicant/group and not to an organization or institution. The grant may be used for salaries, supplies, equipment, travel, fees, insurance, salaries for research assistants, and other research-related costs as specified in the grant application. The grant may NOT be used for institutional overhead, other indirect costs, income tax payments, or tuition. Acceptance of the grant may be subject to institutional rules, regulations and to all applicable tax laws.

Eligibility

- Applicants must be members of MLA.
  - membership options
- Health sciences librarians and information scientists, health professionals, researchers, educators, and administrators are eligible.
- Applicants must have a master's or doctor's degree or be enrolled in a program leading to such a degree and demonstrate a commitment to the health sciences.
- For group research applications, at least one of the group members must qualify according to the above criteria

Submission Checklist

- The online application must be completed and all supporting documents uploaded no later than **November 15**;
- Applicant's curriculum vitae or biographical sketch (in the case of a group application, the primary investigator should submit her/his curriculum vitae or biographical sketch as well as information about each member of the research collaboration group including what role each individual will perform in the research process);
- Detailed research proposal: The proposal should be five to ten pages in length, and it should include all critical elements of the proposed study including historical background and rationale, research aims, budget, research design and methodology, timeline, and plans for disseminating the results;
- The applicant must submit two reference letters from individuals not related to the applicant. The references must be persons who are knowledgeable about the applicant's character, education, and abilities. These letters should also address why the research is significant to the field.
- The applicant should update their MLA member profile page.

Review and Awards Criteria

The MLA Eugene Garfield Research Fellowship Jury will review applications for scientific and technical merit. The jury will follow modified review criteria based on those used for National Institutes of Health grant applications:

- **Research Proposal:** The scientific merit of the proposal, its importance to the field of information science, a historical overview of the proposed research, and its alignment with the stated purposes of the Garfield Fellowship must be included. The proposal should be five to ten pages in length, single-spaced, with twelve-point type.
- **Candidate:** An assessment of the candidate's/group's credentials, including previous academic and research performance, publication activity, or the candidate's/group's potential for research.
- **Research Environment:** An assessment of the quality of the research environment as it relates to the successful conclusion of the research proposal.
- **Research Dissemination Plan:** An assessment of the plan to disseminate the results within and outside the field of health sciences librarianship and health informatics.

Ready to Submit an Application?

- Applications will open next in August 2023.

Previous Grant Recipients

- **2023:** Emily B. Kean, AHIP
- **2022:** Paije Wilson and Vojtech Huser, MD, PhD
- **2021:** *none awarded*
- **2020:** Toluwase Victor Asubiaro
- **2019:** *none awarded*
- **2018:** *none awarded*
- **2017:** Nicole Dalmer
- **2016:** Elizabeth Connor, AHIP
- **2015:** Alyson Gamble
- **2014:** Susan Crawford, AHIP, FMLA, Ann Weller, and John Brundage

Have a question?
Contact MLA

Autobiographical Essays

Prof Dr Eugene Garfield

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Please visit the web link

http://www.garfield.library.upenn.edu/autobiographical.html

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Eugene Garfield had written his autobiography covering
various aspects of life - Personal, Family,
Technical, His contribution to citation index, etc.,
Readers could visit the following
web links, learn and enjoy.

To Remember my Mother
http://www.garfield.library.upenn.edu/essays/v2p535y1974-76.pdf

To remember my father
http://www.garfield.library.upenn.edu/essays/v3p422y1977-78.pdf

How it all began: With a loan from HFC
http://www.garfield.library.upenn.edu/essays/v4p359y1979-80.pdf

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when published in nontraditional forms" ***The Scientist*** **19(20): 24-25, October 24, 2005**
http://garfield.library.upenn.edu/papers/futureofcitationanalysists102405.pdf

From Laboratory to Information Explosions ...
The Evolution of Chemical Information Services at ISI
http://garfield.library.upenn.edu/papers/cheminfoservicesy1999.html

Child Care: An Investment in the Future. Part 1. An Overview of Corporate Chfld
Care Programs and the Effects of Day Care on Young Children
http://www.garfield.library.upenn.edu/essays/v6p031y1983.pdf

Child Care: An Investment in the Future.
Part 2. The 1S1 Caring Center
for Children and Parents
http://www.garfield.library.upenn.edu/essays/v6p038y1983.pdf

All about ice cream or, confessions of an ice cream addict
http://www.garfield.library.upenn.edu/essays/v5p020y1981-82.pdf

Catching the Wind. Part 1. Sailing.
http://www.garfield.library.upenn.edu/essays/v5p039y1981-82.pdf

Catching the Wind. Part 2. Boardsailing
http://www.garfield.library.upenn.edu/essays/v5p045y1981-82.pdf

"How do you do it? Write all those essays I mean"
http://www.garfield.library.upenn.edu/essays/v5p072y1981-82.pdf

What do you do for a living?
http://www.garfield.library.upenn.edu/essays/v4p033y1979-80.pdf

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http://www.garfield.library.upenn.edu/essays/v4p351y1979-80.pdf

What�s a Nice Boy Like You Doing in a Business Like This? or:
What It Takes to be an Information Scientist
http://www.garfield.library.upenn.edu/essays/v2p032y1974-76.pdf

The Who and Why of ISI
http://www.garfield.library.upenn.edu/essays/V1p033y1962-73.pdf

Illusions of Grandeur and other Disappointments
http://www.garfield.library.upenn.edu/essays/V1p460y1962-73.pdf

New Year�s Greetings andnd Other Correspondence�
Keep the Spirit Bright All Year Long!
http://www.garfield.library.upenn.edu/essays/v3p027y1977-78.pdf

Confessions of a Cab Driver
http://www.garfield.library.upenn.edu/essays/v3p116y1977-78.pdf

The Agony and the Ecstasy of Publishing Your Own Book:
Essays of an Information Scientist
http://www.garfield.library.upenn.edu/essays/v3p173y1977-78.pdf

Hotel Horror Stories
http://www.garfield.library.upenn.edu/essays/v3p198y1977-78.pdf

To Remember my brother, Robert L. Hayne
http://www.garfield.library.upenn.edu/essays/v3p213y1977-78.pdf

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On Routes to Immortality
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The "Other" Immortal: A memorable day with Henry E. Bliss
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Philadelphia and ISI are still celebrating the US Bicentennial
http://www.garfield.library.upenn.edu/essays/v2p572y1974-76.pdf

Garfield's Axiom of Economics: "Collecting Money Ain't Easy!"
http://www.garfield.library.upenn.edu/essays/v2p590y1974-76.pdf

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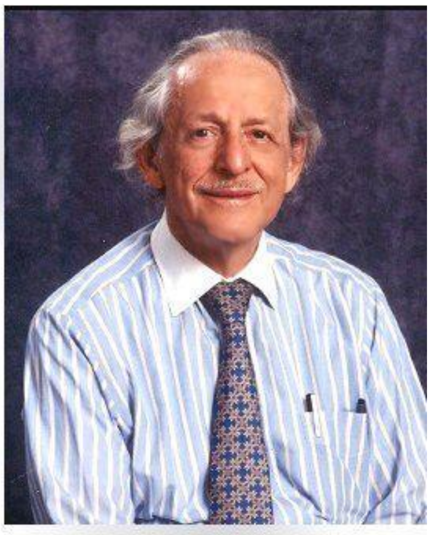

http://www.garfield.library.upenn.edu/

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Prof Dr Eugene Garfield

Please visit the web link

http://www.garfield.library.upenn.edu/pub.html

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To read all his articles / papers (written between 1952 & 2011), please visit the following web links!

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Journal Impact Factor

Trending towards the "future"!

[*Physics Today*: Article dated 17 January 2017]

Author: Melinda Baldwin

DOI:https://doi.org/10.1063/PT.5.9082

> **"Garfield came to see the impact factor as a mixed blessing, 'like nuclear energy'. Although he felt that citation indexing and the impact factor could be remedies for the limitations of peer review, he was uncomfortable with their misuse as performance indicators."**

Elsevier hopes its new CiteScore index will dethrone the impact factor, which has steadily risen in prominence for decades despite persistent criticism.

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Last month scientific publishing giant Elsevier unveiled the CiteScore index, a measure of journal performance based on the number of recent citations. According to Elsevier, a journal's 2015 CiteScore "counts the citations received in 2015 to documents published in 2012, 2013, or 2014 and divides this by the number of documents published in 2012, 2013, and 2014." The first-place journal for 2015 is *CA: A Cancer Journal for Clinicians*, with a CiteScore of 66.45. Nearly a thousand journals at the bottom of the 22 256-journal list have a CiteScore of 0.

In a press release, Elsevier says the CiteScore index "will improve decisions on where to publish, which journals to subscribe to, and when to adjust a journal's editorial strategy." However, CiteScore will have to contend with an older and more familiar rival: the journal impact factor, which has become the best-known metric for a journal's importance despite plenty of pushback throughout its 45-year history.

Eugene Garfield and the *Science Citation Index*

The impact factor was the brainchild of bibliographer Eugene Garfield. He received a bachelor's in chemistry from Columbia University in 1949, then went to work for a project at Johns Hopkins aimed at producing an index of medical journal articles. Garfield became fascinated with the problem of finding relevant articles on a particular topic in the rapidly growing scientific literature. After acquiring his master's from Columbia's library science program, he went into business for himself, offering his indexing services to pharmaceutical companies and corporate researchers such as Bell Laboratories.

Eugene Garfield devised the Journal Impact Factor.

In 1955 *Science* published Garfield's article "Citation indexes for science," in which he proposed publishing an index that tracked citations to individual papers. "The system," Garfield explained, would list "all the original articles that had referred to the article in question." He argued that this type of index would be a far more efficient way for scientists to find relevant papers in a particular field as well as criticisms of problematic papers. He also said the index would be valuable for scientists who wanted to see how their work was being received and for historians interested in assessing the relative importance of different scientific papers.

Garfield's proposal did not immediately catch on. Letters in response to his article pointed to the prohibitive cost of producing such a labor-intensive index. Meanwhile, Garfield started producing indexes for private companies. By the 1960s he had enough capital to undertake his vision of a comprehensive guide to journal citations. In 1964 Garfield's Institute for Scientific Information (ISI) printed the first *Science Citation Index (SCI)*, listing citations of papers published in more than 2200 journals.

Eight years later Garfield released his first journal impact factors. Once again, he announced his idea in an article for *Science*, this one titled "Citation analysis as a tool in journal evaluation." Using the information from the *SCI*, Garfield and his colleagues "decided to undertake a systematic analysis of journal citation patterns across the whole of science and technology."

The result was a list of journals ranked by the average number of citations per research article—a number that he called the impact factor. *Accounts of Chemical Research* took the top slot with an impact factor of 29.285. The top physics journal was *Physical Review Letters*, in 29th place with an impact factor of 4.911. Garfield hoped the ISI's new journal impact factors would help scientists decide which journals to read, highlight cutting-edge areas of research for policymakers and funding bodies, and aid librarians trying to curate the ballooning number of academic journals.

Criticisms of the impact factor

Many scientists questioned the value of citation analysis and Garfield's new metric. Joseph Arditti, a biologist at the University of California, Irvine, wrote to *Science* that some papers might be frequently cited because they were being widely criticized. H. J. M. Hanley at the National Bureau of Standards worried that the metric might create problematic incentives. Tongue in cheek, he advised future scientists to "cite yourself as often as possible; insist that your work be cited in all articles that you review; and automatically pass articles that already contain a sufficient number of citations to you."

Journal	**Impact Factor rank (score), 2015**	**CiteScore rank (score), 2015**
Lancet*	4 (44.002)	242 (7.72)
Nature Materials	7 (38.891)	11 (25.58)
Nature	9 (38.138)	60 (14.38)
Science	16 (34.661)	80 (13.12)
Reviews of Modern Physics	19 (33.177)	7 (32.79)
Living Reviews in Relativity	20 (32.000)	13 (25.19)
Progress in Materials Science*	23 (31.083)	6 (32.97)
Cell*	27 (28.710)	17 (23.62)
Progress in Polymer Science*	29 (27.184)	9 (28.32)
Physical Review Letters	291 (7.645)	454 (5.76)
* Journal published by Elsevier		

Despite such concerns, the impact factor caught on among readers, researchers, and librarians. In 1992 the information firm Thomson Reuters acquired ISI and, with it, the right to issue the list of impact factors. Today many journals tout their impact factor on information pages for potential authors and use the number in advertisements. *Nature*, for example, has an annual sale offering a subscription for the same amount as its current impact factor.

The spread of the impact factor hasn't silenced the index's critics. Two recent studies showed that journal impact factors no longer have a strong correlation with the number of citations individual papers in those journals receive. The measure's ineffectiveness is due to a combination of highly cited papers that skew impact factor calculations and scientists' tendency to read individual articles from many journals rather than one single issue of a top journal.

Other observers have argued that journal editors have manipulated their impact factors by encouraging self-citation, rendering the metric unreliable. Even Philip Campbell, the editor-in-chief of *Nature*, has argued that impact factors are overused. Furthermore, Thomson Reuters makes its rankings available only to subscribers, which makes it difficult for researchers whose institutions do not have access.

Although many people would like to see the impact factor's hold on science shaken, it seems unlikely that Elsevier's CiteScore—or any other alternate metric—will be the solution. CiteScore has one notable advantage over its older rival: Its rankings and data are freely available. But its basic methodology overlaps enough with that of the impact factor that it seems to suffer from the same weaknesses.

Critics are already pointing to potential conflicts of interest with a journal ranking system that is issued by a journal publisher. Notably, CiteScore divides a journal's citations by the total number of articles it has printed, including news articles, editorials, and correspondence—a modeling choice that dramatically drops the rank of some top non-Elsevier journals like *Nature* and *Science*, as well as Elsevier's most famous medical journal, the *Lancet*.

CiteScore probably won't dethrone the impact factor—but that does not mean the 45-year-old metric's future is guaranteed.

Source:
https://pubs.aip.org/physicstoday/Online/12144/Origins-of-the-journal-impact-factor

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List of Top 100 Journals with Highest Impact Factor

The top 100 most influential and prestigious academic and scholarly journals 2023 according to their impact factor are as follows.

Rank	Journal Publication	Journal Home page
1.	Nature – **Impact Factor: 42.78**	View
2.	The New England Journal of Medicine – **Impact Factor: 74.7**	View
3.	Science – **Impact Factor: 41.84**	View
4.	IEEE/CVF Conference on Computer Vision and Pattern Recognition – **Impact Factor: 45.17**	View
5.	The Lancet – **Impact Factor: 59.1**	View
6.	Advanced Materials – **Impact Factor**: **30.85**	View
7.	Cell – **Impact Factor: 38.64**	View
8.	Nature Communications – **Impact Factor: 14.92**	View
9.	Chemical Reviews – **Impact Factor: 60.62**	View
10.	International Conference on Learning Representations – **Impact Factor: 20.03**	View
11.	JAMA – **Impact Factor: 56.27**	View

Rank	Journal Publication	Journal Home page
12.	Neural Information Processing Systems – **Impact Factor: 16.54**	View
13.	Proceedings of the National Academy of Sciences – **Impact Factor: 11.2**	View
14.	Journal of the American Chemical Society – **Impact Factor: 15.42**	View
15.	Angewandte Chemie – **Impact Factor: 15.34**	View
16.	Chemical Society Reviews – **Impact Factor: 54.56**	View
17.	Nucleic Acids Research – **Impact Factor: 16.97**	View
18.	Renewable and Sustainable Energy Reviews – **Impact Factor: 14.982**	View
19.	Journal of Clinical Oncology – **Impact Factor: 44.54**	View
20.	Physical Review Letters – **Impact Factor: 9.161**	View
21.	Advanced Energy Materials – **Impact Factor: 29.37**	View
22.	Nature Medicine – **Impact Factor: 53.44**	View
23.	International Conference on Machine Learning – **Impact Factor: 4.091**	View
24.	Energy & Environmental Science – **Impact Factor: 38.532**	View

Rank	Journal Publication	Journal Home page
25.	ACS Nano – **Impact Factor: 15.88**	View
26.	Scientific Reports – **Impact Factor: 4.379**	View
27.	European Conference on Computer Vision – **Impact Factor: 25.91**	View
28.	The Lancet Oncology – **Impact Factor**: **41.316**	View
29.	Advanced Functional Materials – **Impact Factor: 18.81**	View
30.	PLoS ONE – **Impact Factor: 3.24**	View
31.	IEEE/CVF International Conference on Computer Vision – **Impact Factor: 20.97**	View
32.	Nature Genetics – **Impact Factor: 38.33** (genetics impact factor)	View
33.	Journal of Cleaner Production – **Impact Factor: 9.297**	View
34.	Nature Materials – **Impact Factor: 43.84**	View
35.	Science of The Total Environment – **Impact Factor: 7.963**	View
36.	Circulation – **Impact Factor: 23.6**	View
37.	BMJ – **Impact Factor: 39.89**	View
38.	Journal of the American College of Cardiology – **Impact Factor: 20.59**	View

Rank	Journal Publication	Journal Home page
39.	Applied Catalysis B: Environmental – **Impact Factor: 19.503**	View
40.	Science Advances – **Impact Factor: 14.14**	View
41.	Nano Letters – **Impact Factor: 11.19**	View
42.	Nature Energy – **Impact Factor: 46.5**	View
43.	ACS Applied Materials & Interfaces – **Impact Factor: 9.229**	View
44.	Journal of Materials Chemistry A – **Impact Factor: 12.732**	View
45.	IEEE Access – **Impact Factor: 3.367**	View
46.	Nature Biotechnology – **Impact Factor: 54.91**	View
47.	Nano Energy – **Impact Factor: 17.881**	**View**
48.	Nature Methods – **Impact Factor: 28.55**	View
49.	Nature Nanotechnology – **Impact Factor: 39.21**	View
50.	Cochrane Database of Systematic Reviews – **Impact Factor: 9.266**	View
51.	The Astrophysical Journal – **Impact Factor: 7.413**	View

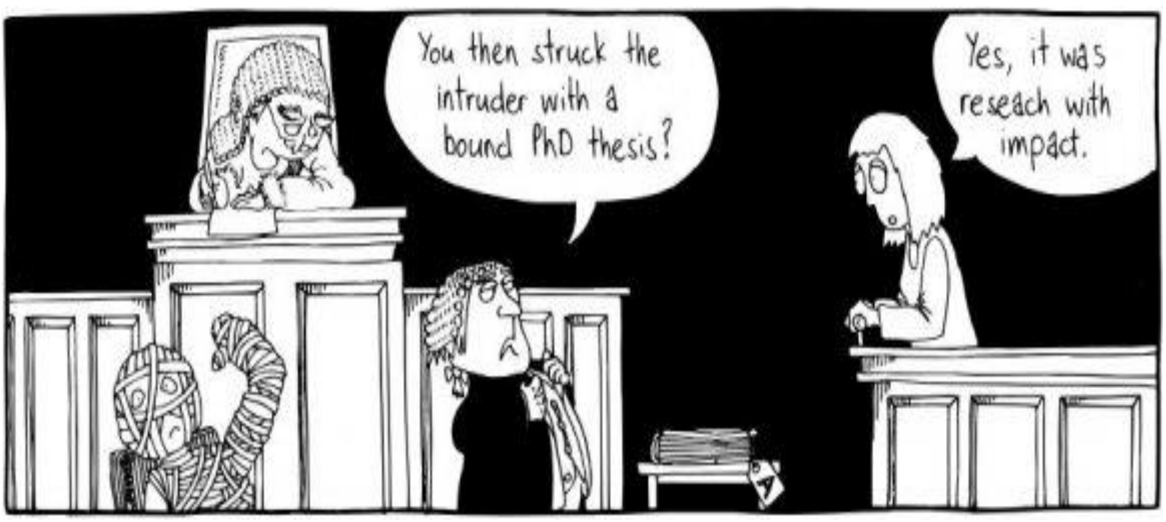
Rank	Journal Publication	Journal Home page
52.	The Lancet Infectious Diseases – **Impact Factor: 20.071**	View
53.	Applied Energy – **Impact Factor: 9.746**	View
54.	European Heart Journal – **Impact Factor: 29.98**	View
55.	Blood – **Impact Factor: 22.113**	View
56.	American Economic Review – **Impact Factor: 9.086**	View
57.	Immunity – **Impact Factor: 31.745**	View
58.	Meeting of the Association for Computational Linguistics (ACL) – **Impact Factor: 19.64**	View
59.	AAAI Conference on Artificial Intelligence – **Impact Factor: 3.055**	View
60.	Gastroenterology – **Impact Factor: 22.68**	View
61.	Neuron – **Impact Factor: 17.173**	View
62.	Journal of High Energy Physics – **Impact Factor: 5.675**	View
63.	IEEE Communications Surveys & Tutorials – **Impact Factor: 25.249**	View
64.	Nature Neuroscience – **Impact Factor: 20.07**	View
65.	Computers in Human Behavior – **Impact Factor: 6.829**	View

Rank	Journal Publication	Journal Home page
66.	Chemical engineering journal – **Impact Factor: 13.273**	View
67.	ACS Catalysis – **Impact Factor: 13.08**	View
68.	Nature Reviews. Molecular Cell Biology – **Impact Factor: 94.44**	View
69.	International Journal of Molecular Sciences – **Impact Factor: 5.923**	View
70.	IEEE Transactions on Pattern Analysis and Machine Intelligence – **Impact Factor: 16.389**	View
71.	Environmental Science & Technology – **Impact Factor: 7.864**	View
72.	Monthly Notices of the Royal Astronomical Society – **Impact Factor: 5.287**	View
73.	Cell Metabolism – **Impact Factor**: **27.287**	View
74.	Nature Physics – **Impact Factor: 20.03**	View
75.	Physical Review D – **Impact Factor: 5.296**	View
76.	Accounts of Chemical Research – **Impact Factor**: **22.384**	View
77.	Nature Photonics – **Impact Factor: 38.77**	View
78.	Nature Climate Change – **Impact Factor: 20.89**	View

Rank	Journal Publication	Journal Home page
79.	Chemistry of Materials – **Impact Factor: 9.811**	View
80.	Molecular Cell – **Impact Factor: 17.970**	View
81.	Clinical Infectious Diseases – **Impact Factor: 8.313**	View
82.	Morbidity and Mortality Weekly Report – **Impact Factor: 13.606**	View
83.	Nature Reviews Immunology – **Impact Factor: 44.02**	View
84.	Gut – **Impact Factor: 23.059**	View
85.	Annals of Oncology – **Impact Factor: 32.967**	View
86.	Cell Reports – **Impact Factor: 9.423**	View
87.	Journal of Business Research – **Impact Factor: 7.550**	View
88.	Clinical Cancer Research – **Impact Factor: 12.531**	View
89.	Frontiers in Microbiology – **Impact Factor: 4.076**	View
90.	Journal of Hepatology – **Impact Factor: 25.083**	View
91.	eLife – **Impact Factor: 8.14**	View
92.	Bioinformatics – **Impact Factor: 6.937**	View

Rank	Journal Publication	Journal Home page
93.	The Journal of Clinical Investigation – **Impact Factor: 14.81**	View
94.	Science Translational Medicine – **Impact Factor: 17.96**	View
95.	Water Research – **Impact Factor: 11.236**	View
96.	Frontiers in Immunology – **Impact Factor: 7.561**	View
97.	Small – **Impact Factor: 13.28**	View
98.	Nature Immunology – **Impact Factor: 20.48**	View
99.	JAMA Oncology – **Impact Factor: 31.78**	View
100.	The Lancet Neurology – **Impact Factor: 44.182**	View

This list will help the readers to find the Top 100 high-impact factor journals related to medical, engineering, and natural sciences in the World.



Glossary

Altmetrics: Also know as alternative metrics; aims to measure web-driven scholarly interactions on the web, including the number of citations in social media sites as well as open peer or crowd-based recommendations or reviews.

5-Year Journal Impact Factor: the average number of times articles from the journal published in the past five years have been cited in the *JCR* year. It is calculated by dividing the number of citations in the *JCR* year by the total number of articles published in the five previous years.

Aggregate Impact Factor: The aggregate Impact Factor for a subject category is calculated the same way as the Impact Factor for a journal, but it takes into account the number of citations to all journals in the category and the number of articles from all journals in the category. An aggregate Impact Factor of 1.0 means that that, on average, the articles in the subject category published one or two years ago have been cited one time.

Article Influence Score: Calculates the relative importance of the journal on a per-article basis and determines the average influence of a journal's articles over the first five years after publication. It is the journal's Eigenfactor Score divided by the number of articles published by the journal. That fraction is normalized so that the sum total of articles from all journals is 1. This measure is roughly analogous to the 5-Year Journal Impact Factor in that it is a ratio of a journal's citation influence to the size of the journal's article contribution over a period of five years.
The mean Article Influence Score is 1.00. A score greater than 1.00 indicates that each article in the journal has above-average influence. A score less than 1.00 indicates that each article in the journal has below-average influence.

Cited Half-Life: The Journal cited half-life is the median age of the articles that were cited in the *JCR* year. Half of a journal's cited articles were published more recently than the cited half-life. Only those journals cited 100 or more times in the *JCR* year have a cited half-life. A higher or lower cited half-life does not imply any particular value for a journal. The Aggregate cited half-life is the median age of the articles that were cited in the *JCR* year. The aggregate cited half-life is an indication of the turnover rate of the body of work on a subject.

Eigenfactor Score: measures the number of times articles from the journal published in the past five years have been cited in the *JCR* year. This calculation is similar to the method Google's PageRank algorithm ranks the influence of webpages; hence, journals are considered influential if they are cited often by other influential journals. Like the Impact Factor, the Eigenfactor is essentially a ratio of number of citations to total number of articles. Unlike the Impact Factor, however, the Eigenfactor counts

citations to journals in both the sciences and social sciences and eliminates self-citations.

Google PageRank: evaluates how many links there are to a web page from other pages and the quality of the linking sites.

g-index: Proposed by Leo Egghe in 2006 to overcome a bias against highly cited papers inherent in the h-index. The g-index is the "highest number of papers of a scientist that received g or more citations, on average" (Schreiber, 2008).

h-index (Hirsch index): measures the impact of a particular scientist rather than a journal. It is defined as the number of papers with citation number higher or equal to h (highest number of publications of a scientist that received h or more citations each while the other publications have not more than h citations each) (Hirsch, 2005). The h-index is included in *Web of Science*. For example, a scholar with an h-index of 5 had published 5 papers, each of which has been cited by others at least 5 times.

Immediacy Index: the average number of times an article is cited in the year it is published. It is calculated by dividing the number of citations to articles published in a given year by the number of articles published in that year. The **journal Immediacy Index** indicates how quickly articles in a journal are cited. The **aggregate Immediacy Index** indicates how quickly articles in a subject category are cited.

Journal Citation Reports (JCR): resource tool for journal evaluation, using citation data drawn from over 7,500 journals from over 3,300 publishers in over 60 nations.

Journal Impact Factor: measures the importance of a journal and is a measure of the frequency with which the average article in a journal has been cited in a particular year or period. Journal impact factor applies only to a journal or groups of journals, but not to individual articles or individual researchers. The impact factor of a journal in a particular year is the number of citations received in the current year to articles published in the two preceding years divided by the number of articles published in the same two years. For example, *Pediatrics* has a 2010 impact factor of 5.391, which means that on average each of its 2008 and 2009 articles was cited 5.391 times in 2010. Citing articles may be from the same journal but most citing articles are from different journals.

Median Impact Factor: the median value of all journal Impact Factors in the subject category. The Impact Factor mitigates the importance of absolute citation frequencies. It tends to discount the advantage of large journals over small journals because large journals produce a larger body of citable literature. For the same reason, it tends to discount the advantage of frequently issued journals over less frequently issued ones and of older journals over newer ones. Because the journal impact factor offsets the advantages of size and age, it is a valuable tool for journal evaluation.

Related Journals: The relatedness (R) values derive from a calculation that takes into account the number of citations from the selected journal title, the total number of articles in the related journal, and the total number of citations from the citing journal. Uses the number of citations from one journal to another to determine a relationship.

Relative Citation Ratio (RCR) is a newer metric, recently endorsed by the National institutes of Health. It is based on weighting the number of citations a paper recieves to a comparison group within the same field.

Self-Citation: Journal Self-Citation is a reference to an article from the same journal. Self-citations can make up a significant portion of the citations a journal gives and receives each year.

SJR (SCImago Journal Rank): a free source that ranks journals and compares journal citation among countries. It expresses the average number of weighted citations received in the selected year by the documents published in the selected journal in the three previous years. This metric doesn't consider all citations of equal weight; the prestige of the citing journal is taken into account.

SNIP (Source-Normalized Impact per Paper): weights citations based on the number of citations in a field. If there are fewer total citations in a research field, then citations are worth more in that field.

Unified Impact Factor: Useful when a journal title changes because the impact factor is generally affected for two years. See *JCR* for how to calculate a Unified Impact Factor.

Journal Citation Reports

Make confident decisions with transparent, publisher-neutral data and statistics

Quickly understand a journal's role in the evolving scholarly publishing landscape to inform manuscript submission, collection development, and portfolio management decisions.

Evaluate journals with a multidimensional view of a journal's impact and influence. View citation metrics, including the Journal Impact Factor and Journal Citation Indicator, alongside descriptive open access statistics and contributor information.

Enhance your journal evaluations

1. **Benchmark your journal's performance against others in a discipline**
   Explore a rich array of citation metrics and descriptive data to make confident portfolio decisions and gain a deep understanding of a journal's influence on the global research community.
2. **Identify journals that are critical to your researchers' and institution's success**
   Ensure your library collections support rigorous research and teaching and make data-driven decisions about your open access strategy.
3. **Discover and select the best-fit journals for your research**
   Find the right journals to publish in to amplify the reach, recognition, and influence of your work.

Trust your source of journal intelligence

Objectivity

- Rely on unbiased journal statistics produced by publisher-neutral experts.

- Consult detailed journal profiles with publication and citation data from the world's original citation index—Web of Science Core Collection.

Selectivity

- Browse journals that have met the rigorous quality standards in the Web of Science Core Collection editorial selection process.
- Quickly locate the most influential journals in your field.
- Save time assessing journals for submission or subscription.

Quality control and transparency

- Remove journals that demonstrate predatory behavior from your process.

- Explore a complete view of citation performance using a dataset built by cover-to-cover indexing and consistent metadata capture.

- Drill down to granular, linked data to thoroughly understand a journal's performance and relationships to other publications.

Release of Journal Citation Reports: 2022

21430
total journals

12828
science journals

6691
social sciences journals

3092
arts & humanities journals

5300
gold open access journals

114
countries

254
research categories

Using the Journal Impact Factor wisely

Web of Science does not depend on the Journal Impact Factor alone in assessing the usefulness of a journal, and neither should anyone else. The Journal Impact Factor should not be used without careful attention to the many phenomena that influence citation rates – for example the average number of references cited in the average article. The Journal Impact Factor should be used with informed peer review. In the case of academic evaluation for tenure, it is sometimes inappropriate to use the impact of the source journal to estimate the expected frequency of a recently published article. Again, the Journal Impact Factor should be used with informed peer review. Citation frequencies for individual articles are quite varied. Journal Citation Reports now includes more article-level data to provide a clearer understanding of the reciprocal relationship between the article and the journal. This level of transparency allows you to not only see the data, but also see through the data to a more nuanced consideration of journal value.

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History of the Science Citation Index

The concept behind citation indexing is fundamentally simple. By recognizing that the value of information is determined by those who use it, what better way to measure the quality of the work than by measuring the impact it makes on the community at large. The widest possible population within the scholarly community (i.e. anyone who uses or cites the source material) determines the influence or impact of the idea and its originator on our body of knowledge. Because of its simplicity, one tends to forget that citation indexing is actually a fairly recent form of information management and retrieval.

There were three factors that led to the development of citation indexing back in the 1950's. With the huge influx of government dollars into research and development following World War II, the research community naturally began to publicly document its findings through the accepted channel of published scientific journal literature. The subsequent burgeoning of the literature created a need for a method of indexing and retrieval that would be more cost effective and efficient than the then-current model of human indexing of materials for subject specific indices. While the subtle judgements made by subject specialists were valuable in giving depth to a subject index, manual indexing was both a more time consuming process and labor intensive. Its costs increased in proportion to the growth of material to be indexed. So the need for a better way of managing information was the first factor.

The second factor was the growing dissatisfaction with the capacity of subject indexing to meet the needs of the active researcher. At this point in time, a subject index could have excessive lag times in adding materials to the indexes of the time; months could pass before researchers in one field would learn of published findings in some other field that had relevance to their own study. Furthermore, there were limitations to the subject indexing in terms of retrieval. Terminology appropriate to one specific discipline would not necessarily have meaning to researchers in another, perhaps overlapping, discipline. At the same time, scientists were recognizing that they had to be aware of, if not completely familiar with, work in a number of different subject disciplines in order to be confident that they had properly grounded the research through an appropriate review of the literature.

Along with this need was the hope that automation might hold the answers, the third and final factor in the development of citation indexing. Computerization in the 1950s was far removed from the desktop environment of today, but there was tremendous excitement over potential benefits to be derived from the application of machines to the generation and compilation of data. The U.S. government hoped that automation could mitigate or even eliminate completely the difficulties of manual indexing. A number of projects were launched by the United States with the intention of investigating these possibilities.

Dr. Eugene Garfield, founder and now Chairman Emeritus of ISI (now Clarivate Analytics), was deeply involved in the research relating to machine generated indexes in the mid-1950's and early 1960's. One of his earliest points of involvement was a project sponsored by the Armed Forces Medical Library (predecessor to our current National Library of Medicine). The Welch Medical Library Indexing project, as it was called, was to investigate the role of automation in the organization and retrieval of medical literature. The hope was that the problems associated with subjective human judgement in selection of descriptors and indexing terms could be eliminated. By removing the human element, one might thereby increase the speed with which information was incorporated in to the indexes. It might also increase the cost-effectiveness of the indexes. Garfield grasped early on that review articles in the journal literature were heavily reliant on the bibliographic citations that referred the reader to the original published source for the notable idea or concept. By capturing those citations, Garfield believed, the researcher could immediately get a view of the approach taken by another scientist to support an idea or methodology based on the sources that the published writer had consulted and cited as pertinent in the bibliography. As retrieval terms, citations could function as well as keywords and descriptors that were thoughtfully assigned by a professional indexer.

In the early 1960s, Eugene Garfield and Associates developed two pilot projects that would test the viability and efficiency of citation indexing. The first project involved the creation of a database that would index the citations of 5,000 chemical patents held by two private pharmaceutical companies. The referenced citations in this instance were to prior patents, the documentation sources that the government patent examiners were using to support a decision to grant or deny a patent. The connections that the patent citation index made were then analyzed with two comparable classification and indexing systems that were currently being used by the participants. Based on this investigation and analysis, the project sponsors determined that citation indexing permitted the retrieval of relevant literature across arbitrary classifications in a way that subject- oriented indexing could not.

A second pilot project in 1962 involved Garfield's recently incorporated enterprise, the Institute for Scientific Information (now Clarivate Analytics), with the United States National Institutes of Health in building an index to the published literature on genetics. This project was far more complex in nature than the patents index. Three databases were built to cover the literature over 1 year, 5 years and 14 years with a varying number of source publications indexed in each. While this project was to test the feasibility and utility of a narrow, discipline-oriented citation index, at completion, it was concluded that the database with the *most broadly based set of source publications* formed the most comprehensive and useful guide to the published literature in the field of genetics. The database for the single-year term had drawn not just on journals that were primarily devoted to the field of genetics research but had drawn as well from a large pool of journals that published genetics papers on a more peripheral or occasional basis. Additionally, while the automated system required a certain level of effort in standardizing the entries from a wide variety of published materials, the project demonstrated the cost-effectiveness of citation indexing as opposed to the expense of traditional subject indexing processes.

While, at the time of the project's completion, the government sponsors chose not to subsidize the development of a national citation database, Eugene Garfield was encouraged to move ahead with the private publication of his multidisciplinary citation index as the first edition of the Science Citation Index (SCI). Available for purchase since 1963, the SCI then and now represents the most comprehensive citation index to the scientific journal literature. Today, the Web-based version of that index covers 5,600 journals across more than 150 scientific disciplines.

Garfield's achievement lay in establishing the utility and objectivity of a citation index in pulling up related papers in published literature that at first glance might not have seemed pertinent to the researcher's inquiry. Today, it is considered to be one of the most reliable of resources in tracing the development of an idea across the multitude of disciplines that are part of our body of scientific knowledge.

Timeline of key events:

- **1960:** Eugene Garfield establishes the Institute for Scientific Information (ISI) in Philadelphia, Pennsylvania
- **1964:** ISI publishes the first Science Citation Index (SCI), fulfilling Garfield's 1955 proposal for citation indexing of the scientific literature
- **1973:** The U.S. National Science Foundation incorporates SCI publication and citation data in the first Science Indicators report on national performance in research

- **1973 / 1978:** ISI expands coverage of the scholarly literature with the introduction of the Social Sciences Citation Index (SSCI) and the Arts & Humanities Citation Index (AHCI), respectively
- **1976:** ISI publishes the first Journal Citation Reports, including Journal Impact Factors and other descriptive statistics
- **1979:** Garfield publishes Citation Indexing – Its Theory and Application in Science, Technology, and Humanities
- **1981:** The ISI Atlas of Science is published, based on research by ISI's Chief Scientist Henry Small and using co-citation to map research topics
- **1988:** ISI introduces the Science Citation Index on CD-ROM
- **1992:** The Thomson Corporation acquires ISI
- **1997:** The Web of Science first launches online, bringing together the SCI, SSCI and AHCI
- **2001:** Essential Science Indicators is introduced – a web-based analytic tool providing data on the output and impact of researchers, institutions, nations and journals, as well as highly cited papers and research fronts
- **2009:** InCites, a platform for in-depth analysis of research performance integrated with complete Web of Science data, is launched
- **2016:** Clarivate acquires the ISI product range from Thomson Reuters Corporation
- **2017:** The life of Eugene Garfield (1925-2017) is commemorated and celebrated September 15-16 in Philadelphia, Pennsylvania
- **2018:** ISI formally re-established within Clarivate, continuing Garfield's original business and intellectual legacy

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Please visit the following web links for more useful and important information:

01] https://clarivate.com/webofsciencegroup/essays/history-of-citation-indexing/

02] https://garfield.library.upenn.edu/papers/barcelona2007a.pdf

03] https://www.researchgate.net/publication/331546716_List_of_Science_Citation_Index_SCI_journals

04] https://www.igi-global.com/journals/indices/web-of-science-science-citation-index-expanded-scie/118

05] https://editorresources.taylorandfrancis.com/understanding-research-metrics/esci/

History of Institute for Scientific Information [ISI]

Source:
https://clarivate.com/the-institute-for-scientific-information/history-of-isi/

Eugene Garfield and his Institute for Scientific Information (ISI) pioneered new methods for indexing and disseminating the world's scientific and scholarly research literature in the second half of the 20th century.

Today, as the research arm of Clarivate, ISI continues Garfield's commitment to provide researchers with high-quality data, advanced tools and key insights to accelerate discovery and innovation.

Building a foundation for information science

Garfield introduced the concept of citation indexing for the sciences in 1955 and ISI produced the first Science Citation Index (SCI in 1964. Citation indexing revolutionized information retrieval. By recording and linking the cited references that authors attached to their papers, the SCI represented an "association of ideas index."

It was an idea before its time, proving Garfield a visionary as well as an innovator. By organizing information through a network of citation connections, Garfield anticipated web hyperlinking and the Google Search algorithm by three decades.

From its foundation in 1960, ISI introduced a range of current awareness and information retrieval products and services covering the literature of the sciences, social sciences and humanities.

A Social Sciences Citation Index (SSCI) was introduced in 1973 and an Arts & Humanities Citation Index (AHCI) in 1978. Several products focused on the chemical sciences, such as Index Chemicus, the ISI's first offering in 1960.

The Journal Citation Reports, introduced in 1976, collated journal-to-journal citations to help librarians and publishers understand the communication system of the science and social sciences literature, as

well as the influence and prestige of specific titles. Among other indicators in the product, the most popular was the Journal Impact Factor.

Other ISI products were designed to keep researchers up to date on new publications in their fields, such as Current Contents, a weekly bulletin presenting the content pages of journals, eventually issued in seven field-specific editions.

SCI data also served as a foundation for quantitative studies in the history and sociology of science and eventually gave birth to the field of scientometrics.

Carrying the torch of Garfield's intellectual legacy

In 1992, the Thomson Corporation acquired ISI. Thomson merged with Reuters in 2008 to form Thomson Reuters. In 2016, the scientific and scholarly information business of Thomson Reuters, including the products and services of the former ISI, was spun out to private ownership and rebranded as Clarivate.

ISI was revived as a research division within Clarivate in 2018 to conduct scientometric research, to advise the company on the content and features of its products, and to offer guidance to the research community on best practices in the use of quantitative indicators in the evaluation of research. It also maintains the foundational knowledge and editorial rigor upon which the Web of Science index and its related products and services are built.

ISI's reports and publications and participation in events and conferences play a crucial role in extending and improving the knowledge base that is essential to our colleagues, partners and all those who deal with research in academia, government organizations, corporations, as well as funders and publishers.

ISI Highly Cited

"ISI Highly Cited" is a database of "highly cited researchers"—scientific researchers whose publications are most often cited in academic journals over the past decade, published by the Institute for Scientific Information. Inclusion in this list is taken as a measure of the esteem of these academics and is used, for example, by the

Academic Ranking of World Universities. It was founded under ISI and as of 2018 continues under the same name at Clarivate.

The methodology for inclusion is to consider papers in the upper first percentile based on citation counts of all articles indexed in the Scientific Citation Databases and published in a single, fixed year. Papers in the upper first percentile with respect to their year of publication are called highly cited papers. Each paper in the data is assigned to one or more of 21 categories, based on the ISI classification of the journal in which the article was published. The Highly Cited Researchers list is compiled by selecting, in every field, those researchers with the highest number of highly cited papers in a 10-year, rolling time period. The number of highly cited researchers varies from field to field and is determined accordingly to the total number of researchers contributing to the single field.

The categories are as follows:

Agricultural Sciences
Biology & Biochemistry
Chemistry
Clinical Medicine
Computer Science
Ecology/Environment
Economics/Business
Engineering
Geosciences
Immunology
Materials Science
Mathematics
Microbiology
Molecular Biology & Genetics
Neuroscience
Pharmacology
Physics
Plant & Animal Science
Psychology/Psychiatry
Social Sciences - General
Space Sciences

The publication list and biographical details supplied by the researchers are freely available online, although general access to the ISI citation database is by subscription.

ISI Web of
KNOWLEDGE
Transforming Research

Institute for Scientific Information Headquarters: Philadelphia

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PhD Thesis

"An Algorithm for Translating Chemical Names to Molecular Formulas"

Submitted to and accepted by the
Department of Linguistics of the
University of Pennsylvania
[17 July 1961]

Institute for Scientific Information
33 South 17th Street
Philadelphia, 3, Pennsylvania

Full Thesis is enclosed!

An Algorithm for Translating Chemical Names to Molecular Formulas

EUGENE GARFIELD

INSTITUTE FOR SCIENTIFIC INFORMATION
33 SOUTH 17th STREET • PHILADELPHIA 3, PENNSYLVANIA

PREFACE TO THE FIRST ISI EDITION

This varityped version of my doctoral dissertation has been prepared primarily to satisfy the many requests I received for copies of the original manuscript. With the exception of minor typographical changes and those noted below in the section on Transformations, the only other changes have been in the arrangement of the indexes, bibliography, etc. which had to conform to university conventions. However, in this edition the indexes, etc. have been placed at the end.

The original manuscript was typed primarily by my secretary, Mrs. Sylvia Shapiro. The varityping in this edition was done by Mrs. Joan M. Graham. Proofreading was performed by Mrs. Joan E. Shook and Mr. Walter Fiddler. Mr. Fiddler found errors of omission in the section on Transformations which have been corrected by the addition of footnotes. He also found many errors in the copying of chemical names and formulas in both the original and the final manuscript. This only strengthens my belief that an arduous intellectual task such as naming a chemical or calculating its formula is most consistently performed by a machine.

I also want to thank collectively, the many other persons who helped in the preparation of this work through suggestions and participation. The dissertation, as accepted by the Department of Linguistics of the University of Pennsylvania, went through several revisions before it was accepted. Many of these changes resulted from different interpretations of the *morpheme, allomorph,* etc. Linguistics is not yet so precise that one can prescribe a discovery procedure. Quite simply, this means that linguistic data can be interpreted in many useful ways. For the reader who is interested in pursuing the theoretical background of this statement further, I recommend Noam Chomsky's *Syntactic Structures* (Mouton & Co. 'S-Gravenhage, 1957) especially pages 17 and 56.

Most of the readers of this treatise will not be trained in linguistics. However, I do not feel that anyone interested in learning the procedures described will find the reading too difficult, even though the work was not written as a textbook. It is my intention to supplement this work by a textbook that will enable scientists and librarians to use chemical nomenclature for literature searches and for indexing without getting into the detailed understanding of organic chemical structure and theory. As a follow-up of this dissertation, work is now in progress on the completion of the lexicon of chemical morphemes. In the present work, linguistic analysis was confined primarily to acyclic chemistry while definitely establishing the feasibility of handling cyclics. To complete the linguistic analysis now requires considerable work. For example, the analyses must account for the difference in meaning of *oic acid* when it occurs with *pentanoic acid* and *benzoic acid.* This example also illustrates the futility of any syllabic approach to the study of chemico-linguistics.

I wish to stress that it is not necessary for the reader to wait for the appearance of the above-mentioned lexicon in order to use the algorithm (procedures) described here. This is especially true for those with training in organic chemistry, that is, have already memorized enough chemical nomenclature to carry through the simple calculations.

In closing I should like to encourage my readers to communicate with me concerning any portion of this work.

Eugene Garfield
INSTITUTE FOR SCIENTIFIC INFORMATION
Philadelphia 3, Pa.

July 17, 1961

PREFACE

This dissertation discusses, explains, and demonstrates a new algorithm for translating chemical nomenclature into molecular formulas. In order to place the study in its proper context and perspective, the historical development of nomenclature is first discussed, as well as other related aspects of the chemical information problem. The relationship of nomenclature to modern linguistic studies is then introduced. The relevance of structural linguistic procedures to the study of chemical nomenclature is shown. The methods of the linguist are illustrated by examples from chemical discourse. The algorithm is then explained, first for the human translator and then for use by a computer. Flow diagrams for the computer syntactic analysis, dictionary look-up routine, and formula calculation routine are included. The sampling procedure for testing the algorithm is explained and finally, conclusions are drawn with respect to the general validity of the method and the direction that might be taken for future research. A summary of modern chemical nomenclature practice is appended primarily for use by the reader who is not familiar with chemical nomenclature.

ABSTRACT

An algorithm for translating directly from chemical names to molecular formulas is described. The validity of the algorithm was tested both manually and by computer. Molecular formulas of several hundred randomly selected chemicals were calculated successfully, verifying the linguistic analyses and the logic of the computer program.

The algorithm for manual human translation consists of eight simple operations. The procedure enables non-chemists to compute molecular formulas quickly without drawing structural diagrams. The machine translation routine is rapid and requires a program of less than 1000 instructions. If the experimental dictionary were expanded to include low frequency morphemes, formulas for all chemical names could be handled.

The problem of chemical nomenclature is discussed in terms of the information requirements of chemists. The approach of the linguist to the problem of nomenclature is contrasted with that of the chemist. It is shown that there is only one language of chemical nomenclature though there exist many systems of nomenclature. The difficulties in syntactically analyzing *Chemical Abstracts (C. A.)* nomenclature results from *C.A.*'s ambiguous use of morphemes such as *imino*, not the use of so-called *trivial* nomenclature. The more *systematic I.U.P.A.C.* nomenclature includes idiomatic expressions but eliminates all homonymous expressions.

The structural linguist tries to describe a language compactly. While this study does not not include a complete grammatical description of chemical nomenclature, all of the basic facets

of the most frequently occurring segments. Approximately forty morphemes such as {*o*, *e*, *y*} and allomorphs such as *thi* and *sulf* were isolated. A list of their 200 actual co-occurrences were compiled. These studies are particularly valuable in identifying idiomatic expressions such as *diaz*, the meaning of which cannot be computed from the referential meanings of *di* and *az*. Morpheme classes are illustrated by the *bonding* morphemes (*an*, *en*, *yn*, *ium*, etc.) and the homologous *alkyl* morphemes *meth*, *eth*, *prop*, *but*, etc.

The syntactic analyses include the demonstration of transformational properties in chemical nomenclature as e.g. in *primary amines* (R–N) where *aminoRane* $\rightleftharpoons$ *Rylamine*. To complete the grammar one would have to expand the inventory of morphemes, morpheme classes, and the list of transformations. Chemical name recognition is not simply a word-for-word translation procedure. Rather the syntactic analysis required is comparable to the procedure employed by Harris, Hiz, et al (Transformations and Discourse Analysis Projects, Univ. of Pennsylvania) for normal English discourse. The structural linguistic data is supported by a summary of *I.U.P.A.C.* rules for generating chemical names.

In order to relate this study to the general problem of chemical information retrieval, the historical development of chemical nomenclature is traced from the 1892 Geneva Conference to the present. The relationship between nomenclature, notation, indexing and searching (retrieval) systems is discussed. In particular, the need for linguistic studies to solve the intellectual facet of the "retrieval" problem is discussed in contrast with the manipulative aspects which are more readily amenable to machine handling. The problem of synonymy in chemical nomenclature must be resolved if computable syntactic analyses of chemical texts are to be used for mechanized indexing. The completion of the detailed grammar of chemical nomenclature would not only permit the calculation of molecular formulas but also the generation of structural diagrams, systematic names, line notations, and other information required in machine searching systems. With suitable modifications the procedures could easily be applied to foreign nomenclature.

The field of chemico-linguistics is of interest to the organic chemist as it can improve methods for teaching nomenclature. Similarly, for the linguist chemical nomenclature is a fertile field of study. One can control the experimental conditions more easily than in normal discourse. However, conclusions can be drawn which may have more general application.

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ORGANIC CHEMICAL NOMENCLATURE -- HISTORICAL AND BACKGROUND INFORMATION

The Contradictory Goals of Chemical Nomenclature

"It is possible in the domain of organic chemistry to give several names to the same compound. This state of affairs has on the one hand the great advantage of permitting clear expression of thought and of rendering it easier to bring out analogies in structure wherever this is useful." [*J Am. Chem. Soc.* 55, 3905(1933)].

These remarks are quite indicative of the general state of affairs of chemical nomenclature. They are the opening sentences of the 1930 "Definitive Report of the Commission on the Reform of the Nomenclature of Organic Chemistry" (opus cited, p. 3905) and like much that is said about nomenclature, the one sentence contradicts the other.

If it is possible to name the same chemical compound in two or more different ways, does this *really* permit clear expression of thought. It depends on one's orientation. For the speaker, synonyms do indeed allow for greater freedom of expression and the ability to bring out subtleties that might otherwise be difficult to make. For the listener, such freedom of expression on the part of the speaker may result in complete loss of comprehension. To complete the round of contradictions we find in the next sentence: "But on the other hand a multiplicity of names for the same substance constitutes a serious obstacle in the preparation of indexes." (opus cited, p. 3905).

Oral Communication Versus Indexing

Thirty years ago it was not yet quite apparent to experts in chemical nomenclature that their attempts to modify prevalent nomenclature for indexing purposes actually might be making oral and written communication even *more* difficult. It is not my purpose or intention to criticize the work of these experts. The purpose of these introductory remarks is to indicate that committees on chemical nomenclature are indeed faced with the baffling dichotomy of trying to serve the purposes of oral *communication* on the one hand and the needs of *indexing* on the other. This is like trying to get people to speak the King's English in order to simplify the task of preparing dictionaries. The inability to make these two functions blend is quite obvious if one examines, briefly, the history of organic nomenclature for the past seventy-five years.

Geneva Nomenclature

Modern chemical nomenclature "officially" began in 1892 [Pictet, *Arch. sci. phy. nat.* **27**, 485-520(1892)][Tiemann, *Ber.* **26**, 1595-1631(1892)] at the well known Congress of Geneva. All students of elementary organic chemistry are still taught the "Geneva" system though some teachers

may now call it the I.U.P.A.C. system. The next major revision of the Geneva system came with the 1930 Report mentioned above. Thirty-eight years later "the intent of the Geneva Congress had not been realized" i.e., Rule I enabled each chemical to be named officially so that it would "be found under only one entry in indexes and dictionaries." (opus cited, p. 3906)

I.U.P.A.C. Nomenclature

The next major report on Organic Chemical Nomenclature came almost thirty years later and is known as the 1957 Report [*J. Am. Chem. Soc.* 82,5545-84(1960)]. It is important to note that the 1957 Report contributed nothing to affect this dissertation. Most of the report is devoted to cyclic compounds. The portion of acyclic chemistry which is discussed, the hydrocarbons, does not in any way affect the linguistic aspects of my research. For that matter, as is noted below, it does not affect the basic description of organic nomenclature.

The nomenclature of so-called simple functions, i.e. substances which contain only one kind of function such as acids, alcohols, etc. are not covered in the 1957 Report. The same is true of the complex functions.

Constant Activity in Nomenclature Field

The failure of the 1957 Report to treat the entire domain of organic nomenclature does not mean that there has not been a great deal of attention devoted to chemical nomenclature during the past thirty years. On the contrary, as Austin M. Patterson noted in 1951 there were so many committees on nomenclature that it was necessary to compile a directory of them. (*Chem. Eng. News* May 28, page 2181, cited in his "Words about Words" Washington, *Amer. Chem. Soc.*, 1957). This is a collection of nomenclature columns written by Patterson for the weekly organ of the Society, *Chemical and Engineering News*.

No Basic Change

Looking at the development of organic nomenclature from the viewpoint of structural linguistics one is forced to conclude that while there are changes in the Geneva System contained in the 1930 Report, the former system is retained basically intact. Only minor details were modified.

The present situation in organic chemistry may be described by posing the following questions. If I had been ignorant of the 1930 and 1957 Reports on organic nomenclature and had compiled the list of morphemes and their corresponding syntactic rules, how accurately would this analysis describe organic nomenclature as it is used today. At least 90% of the new chemicals made each year would be recognized by a grammar based on the Geneva System. It would be an interesting study to make an *exhaustive* analysis of chemical nomenclature prior to 1892. This would determine

the basic list of morphemes available to the chemist at the Geneva conference. However, such a comparison was not germane to the particular research involved in this dissertation.

While it is true that "official" nomenclature began at the Geneva conference, examination of the 1892 Report and others (e.g. Armstrong, *Proc. Chem. Soc.* 1892,127-131) and similar examination of earlier nomenclature practice reveals that the morphology of organic chemistry not only remained essentially the same in the 1930 and 1957 Reports, (which were presumably revisions of the 1892 Geneva Report), but even the Geneva conference did not contribute any major morphological changes in organic nomenclature. The Geneva chemists simply accepted the morphological pattern already in use and codified it. In other words, a morphological analysis of organic nomenclature conducted in 1891 would have produced almost exactly the same results as an analysis conducted after the Geneva Conference in 1892.

This is not to underestimate the value of the Geneva Conference. It has served a useful function in teaching nomenclature, as there was not then available any internationally accepted system that teachers could use. However, while the teaching of organic nomenclature was not quite formalized in 1891, the terminology acquired in studying elementary organic chemistry as e.g. by using an 1890 textbook would be not significantly different than that which would be acquired in reading the same textbook in its 1920 edition in which the Geneva system is adopted.

Longest Versus Shortest Chain Structure

The Geneva Conference *did* make some significant contributions to the syntactical description of organic nomenclature, or at least to solidification of syntactical practices used by many but not as universally as was the morphology. Thus, *triethylmethane* became *3-ethylpentane*. The example of *triethylmethane* demonstrates the point well. The morphemes *tri, eth, yl, meth, an, e* were not new. Neither were the morphemes *eth, yl, pent, an, e* in *ethylpentane*. The new rules specified the selection of the latter combination of morphemes for the chemical $CH_3-CH_2-CH(CH_2-CH_3)-CH_2-CH_3$ by establishing the syntactical principle that the "parent" structure shall be the one which contributes the *longest* possible chain of carbon atoms. The older method of naming this chemical had an *implied* syntactic structure where one named chemicals in terms of the *shortest* chain. The same diagram can be written $(CH_3-CH_2)_3-CH$. There are historical reasons for this change.

Rapid Change in Syntax – Not Morphology

Early organic chemistry naturally was concerned with chemicals of simpler structure such as *methane* gas. As the knowledge of chemical structure increased, chemicals like *pentane* were easier to understand, but still the Geneva chemists could not foresee the rapid development of or-

ganic chemistry that would take place, in which it would again become necessary to modify the syntax of nomenclature but not the morphology. This would seem to be the opposite of historical development of languages where it is the morphemes which change more rapidly than syntax.

Reading Organic Chemistry as a Language

Contrary to general belief, organic chemical nomenclature is relatively simple. It is not to the credit of many teachers of organic chemistry that many students are frightened away from organic chemistry because they are confronted too early and quickly with what seem to be very complicated chemical words. Students are not taught the basic elements of organic nomenclature before they begin the formal study of the actual experimental science. This is unfortunate. One can recall that it use to be a requirement for pre-medical students to study Latin. This was really not necessary to the study of medicine. However, having removed Latin from the medical curriculum there remains a vacuum. Special preparation in the language of medicine is needed to fill this vacuum. Similarly, the special language of organic chemistry should be taught first.

Implications for Teaching Organic Chemistry

I believe there *are* implications to be drawn from this dissertation for the teaching of organic chemistry. Teaching chemistry cannot be divorced from the general problem of chemical communication. However, I cannot hope to pursue, in detail, all the derivative problems related to chemical nomenclature.

Increased Volume of Chemical Literature

As was stated in the opening paragraph, the earlier international committees on organic nomenclature tried to resolve *simultaneously* the problem of communicating and indexing chemistry. If the problem of indexing chemicals was already a problem in 1892, it is quite understandable that the emphasis on the indexing implications of nomenclature have increased. Whereas a few thousand new chemicals were prepared each year at the turn of the century, over 75,000 new chemicals were prepared by the world's chemists in 1960 alone (cf. E. Garfield, *Index Chemicus*, 1st Cumulative Index, **1961**, 33.)

Notation Systems

This volume has increased the preoccupation of nomenclature experts with indexing requirements. This includes not only conventional indexing systems, but also systems which will employ machines both for listing chemicals in the conventional fashion and also for new types of machine searching. The newer "nomenclature" systems, e.g. G.M. Dyson [(1947) Longmans, N.Y. 1949]and

W.J. Wiswesser (A Line Formula Chemical Notation, Crowell, N.Y., 1954) have completely discarded the semblance of English and employ completely symbolic representations. These so-called cipher or notation systems do undoubtedly simplify the problem of arraying formulas in indexes, just as notation systems simplify the problem of arraying books on a library shelf. However, just as library classification systems cannot place the book on more than one shelf at a time, using a notation system, per se, does not resolve the need to locate chemicals in more than one place in the index.

The various notation systems which have been proposed purport to avoid the pitfalls of nomenclature. None of them have been designed on the basis of a formal linguistic analysis of nomenclature. Rather, their inventors have been preoccupied with such problems as economy of notation and the ability to use the system simultaneously for the unique identification of chemical compounds as well as for generic searching. This now introduces a factor which begins to explain the background purpose of this research program.

Objectives of Linguistic Analysis

One can perform linguistic analysis with many different objectives in mind. Indeed, it is quite possible to visualize a situation in which a language might be analyzed without the linguist acquiring a speaking knowledge of that language. Similarly one can analyze nomenclature either with the idea of mastering the techniques of naming chemicals or one may be more interested in uncovering new methods of classifying chemicals. Since modern formal linguistics certainly helps one to perceive semantic as well as grammatical categories more directly than the older, more intuitive methods, (comparable to *a priori* elucidation of chemical classifications) then it is of interest to explore the possibilities of using formal structural linguistics in studying the problem of chemical information retrieval. I first discussed this possibility with Prof. Z. Harris in 1955 (E. Garfield, private communication "Structural Linguistics and Mechanical Indexing, 1955).

Information Requirements of Chemists

To completely understand the *raison d'etre* of this research, it is necessary to review some of the general information requirements of the chemist and how chemical nomenclature is related to these requirements. The organic chemist may spend years attempting to synthesize a particular chemical. In order to avoid the possibility of repeating experiments which were performed by others, he must have access to comprehensive indexes. Such indexes are typified by the *Chemical Abstracts* (C.A.) Subject and Formula Indexes (Chemical Abstracts, Columbus, Ohio).

In the C.A. indexes one can find a specific chemical by either of two methods. If one understands the C.A. system of chemical nomenclature then one can name a particular chemical in

which one is interested and look for it in the alphabetic subject index. On the other hand, if one does not have mastery of the C.A. nomenclature system one still has the option to use the Formula Index. (Incidentally, not more than a few hundred chemists in this country have a complete mastery of the C.A. system. Three years of full-time indexing work are generally required to train a graduate organic chemist to be an indexer for *Chemical Abstracts.)*

Formula Indexes

The Formula Index is a simple device in which each chemical is listed in alpha-numeric order according to the number of carbon and other atoms contained in it. *Ethyl alcohol (ethanol)* is listed under C_2H_6O while *acetic acid (ethanoic acid)* is $C_2H_4O_2$. By simply counting the number of carbon and other atoms in the chemical, the chemist can compute the molecular formula. With no special training he can use the formula index to find the C.A. name of the chemical in which he is interested.

I wish to make clear that these are oversimplified statements for the purpose of explanatory clarity. In actual practice one must be very cautious in calculating a molecular formula as the more complex molecules prepared today can even be difficult to depict in ideographs. This then brings up another vital question, which is, the use of structural diagrams (ideographs).

Structural Diagrams

While a chemist may frequently *not* be able to name a chemical from a structural diagram, according to the I.U.P.A.C. or C.A. systems, he *can* usually draw a diagram from a name. In order to calculate the molecular formula of a complex molecule the chemist will invariably draw its structural diagram and then proceed to add the number of carbon and other atoms. A particularly annoying aspect of working with someone else's diagram is the frequent practice of omitting some of the hydrogen atoms in the diagrams. Hydrogen atoms as such are usually of little interest to the chemist.

All existing methods of naming, indexing, coding and ciphering chemicals are based on the assumption that the chemist will first provide a structural diagram. It is important to keep this in mind when comparing methods of handling chemical information. For example, when a chemical originally reported by name is indexed by *Chemical Abstracts* the indexer will *first* draw a structural diagram. He will then proceed to rename it "systematically". More often than not, the newly assigned name will be completely incomprehensible to the chemist who first prepared the chemical. The indexer will also use the structural diagram to calculate the molecular formula which, as we have seen, is very useful to the chemist in finding a chemical in a formula index.

Molecular Formulas in Analytical Chemistry

The molecular formula also plays another important role in chemical research as it is essential in analyzing chemicals to identify them through molecular or empirical formulas. The empirical formula shows the ratio between carbon, hydrogen and other atoms. For this reason, it is generally required that the chemist report the "calculated" molecular formula of each new compound he prepares when submitting a paper to a scientific journal. It is significant that a large number of the molecular formulas reported by authors contain errors. This statement is based on my personal experience in editing the indexing of more than 100,000 new chemical compounds. Surprisingly few chemists know the "odd-even" rule which requires that the hydrogen count is an odd number if there is an odd number of other atoms present. Most of the errors are in the hydrogen count. "The calculation of correct molecular formulas requires great care and checking is justified." (E. J. Crane: "*C A Today – The Production of Chemical Abstracts*, Amer. Chem. Soc., Washington, D.C., 1958, p. 86).In this same book Dr. Crane also discusses the frequent errors found in original journal articles (opus cited p. 74).

Generic Searches

While the subject and formula indexes to *Chemical Abstracts* are designed primarily to help the chemist find a specific chemical in which he is interested, they are not especially useful when he is trying to find a chemical of related structure. Indeed, in this case the chemist may not even know the existence of a particular chemical before he begins his search. Thus he may be interested in learning whether any member of a class of chemicals has been reported in the literature as e. g. *hexanols*. Generic searching is not always practical with the conventional indexes. For this reason other methods, both manual and machine, are now extensively employed.

Chemical-Biological Coordination Center Code

The most comprehensive classification system designed for searching chemicals generically is the system of the now defunct Chemical-Biological Chemical Coordination Center of the National Research Council. This system is based primarily on the work of Prof. D. Frear of the Pennsylvania State University (CBCC Chemical Code, National Research Council, Washington, 1948.)

Modifications of CBCC Needed

The CBCC chemical code is an elaborate hierarchial system of classification based on *a priori* assumptions concerning the classes one may wish to search in large files of chemicals. While the CBCC system is quite useful, almost without exception, chemists who employ it must make modifications in particular parts of the classification schedules to differentiate more

precisely their particular chemical interests. For example, a steroid chemist would expand certain sections of the code where it is not sufficiently specific to distinguish large numbers of chemicals which might otherwise receive the same code number. This is the same problem that librarians encounter in using systems such as the Dewey Decimal System and the Library of Congress classification system.

Thus the laboratory chemist has two general requirements in searching for chemicals – the search for a *specific* chemical and the *generic* search. Turning from the chemist who is the user of indexes, what is the problem of the chemist who prepares these indexes.

The Indexer's Problem

In attempting to satisfy the information requirements of the lab chemist, the chemical indexer must deal with dozens of foreign languages in which chemical papers are written. He must also deal with the different synonym-producing-systems of naming the same chemical in each foreign language. In other words, French chemists not only have their little devices for naming chemicals, but in France, as in other countries, each chemist has certain preferences for naming chemicals in which he is a specialist.

Nomenclature Requires More Than Cooperation

The last comment may sound strange when one considers the obvious desire and willingness of chemists all over the world to cooperate in using standardized nomenclature. However, nomenclature is a problem that is far beyond the mere question of cooperation. It takes more than good intentions to resolve problems that arise from the vagaries of language. The plethora of chemical synonyms presents a formidable obstacle to the chemical indexer. If some method could be found for indexing chemical names without the many costly and enervating steps now required, a worthwhile step would have been made in documenting the literature of chemistry. This problem has great economic significance to indexer and user alike. The budget of Chemical Abstracts is over five million dollars per year.

Machine Indexing

The use of machines to perform indexing is by now no novel idea. My own investigations on the use of computers to index chemical information began in 1951 as a member of the Johns Hopkins Machine Indexing Project (cf. W.A. Himwich, H. Field, E. Garfield, J. Whittock, S.V. Larkey, Welch Medical Library Indexing Project Reports, Johns Hopkins University: Baltimore, 1951, 1953, 1955.)

Manipulative Versus Analytical Aspects of Indexing

In September of 1952, I presented an oral report on a tentative method for preparing the indexes to *Chemical Abstracts* before the American Chemical Society's Committee on C.A. Mechanization. However, most of the early work in the use of computers for scientific documentation concerned itself with the *manipulative* aspects of the problem rather than the *analytical* aspects. (cf. E. Garfield: Preparation of Printed Indexes by Machines, *Am. Documentation*, 6:68–76, 1955 and Preparation of Subject Heading Lists by Automatic Punched-Card Techniques, *J. Documentation*, 10:1–10, 1954).

In private communication to Prof. Arthur Rose, Pennsylvania State University, then chairman of the American Chemical Society Committee on C.A. Mechanization, the relationship between the problem of mechanical translation of languages and the problem of mechanical analysis of scientific literature was discussed. As the years have passed, the general awareness that the linguistic problems of indexing are far more significant than the manipulative aspects has increased. All workers in the field of information retrieval are now more conscious of the need to concentrate on problems of using computers as a substitute for the costly *intellectual* analysis required to index scientific documents by the conventional criteria as well as new criteria.

Soviet and British Nomenclature

In recent years Soviet scientists have also been devoting more attention to these problems as, for example, in the work of Tsukerman and Vladutz (cf. A.M. Tsukerman & A.P. Terentiev, Chemical Nomenclature Translation, *Proc. Intl. Conf. for Standards on a Common Language for Machine Searching and Translation*; New York, Interscience, 1961). Indeed, what it now a Soviet textbook of organic chemical nomenclature was first published in 1955 (cf. A.P. Terentiev et al, *Nomenklatura Organicheskikh Soedmionii*, Moscow, 1955) (simultaneously published in German translation as "*Vorschlage zur Nomenklature Organischer Verbindungen*", Moscow, 1955.) It is an excellent treatment of the general subject of nomenclature. There are not too many extant works to which it can be compared. Cahn's recently published work (R.S. Cahn, *An Introduction to Chemical Nomenclature*, London, 1959) is written for the lay chemist. However, as Editor of the *Journal of the Chemical Society of London*, Cahn and Cross also prepared the "*Handbook for Chemical Society Authors*", (Special Publication No. 14, London, The Chemical Society, 1960) which has many invaluable comments on I.U.P.A.C. as well as British and American nomenclature. It also gives the dates each rule was adopted.

American Nomenclature

The definitive American work on nomenclature is a publication known to most organic chemists – "*The Naming and Indexing of Chemical Compounds by Chemical Abstracts*" (Columbus,

Chemical Abstracts, 1957). The work is simply a reprint with comments of introductory remarks to the 1954 C.A. Subject Index. Neither this work nor that of Cahn can be considered to be a critique of nomenclature. That no really complete critique of chemical nomenclature is available is not surprising. This is a subject which has represented a lifetime of work for several eminent chemists among others A.M. Patterson, E.J. Crane, L.T. Cappell and the staffs of several publications in this country and abroad.

Accelerated Interest in Mechanical Analysis

The increasing availability of high-speed, high-density storage computers has now accelerated interest in the mechanical analysis of texts. It is not surprising that many individuals and teams are working simultaneously on many aspects of this problem. The possible use of computers for mechanical analysis of texts is not just an academic question involving the study of language, information theory, etc., in an academic sense, not that there can be too much research on these subjects. However, as one witnesses the growing volumes of scientific publications and the increasing difficulties of finding qualified personnel with scientific and indexing training one must be tempted to explore the full potential of the computer for every facet of indexing work. As the editor of a chemical index, I am only too well aware of the need for such assistance, even though a complete resolution of all extant problems seems now to be "futuristic". What then are the possibilities of using the computer to perform such intellectual analyses?

INTELLECTUAL INDEXING TASKS REQUIRING STUDY

Mechanical Reading Device

In the first place, one would like to have available a device for mechanically reading the words. This would avoid the costly step of manually creating a computer input in machine language. For example, one would like to index chemical papers merely by underscoring pertinent chemical names in a text. These words then would be analyzed by the computer. This was the basic premise of Frome's experiment (cf. J. Frome, U.S. Patent Office, Report No. 17, 1959).

Selective Word Recognition – Copywriter

In the work of indexing for the *Index Chemicus*, chemists must underscore pertinent chemical names and formulas. At present, there is no device available which would permit one to *selectively* "read" or "sense" printed texts, though the character recognition problem is gradually finding a solution. Large sums are now going into research on character recognition devices. However, the immediate prospect of devices which can simultaneously read the hundreds

of different typographical styles now employed is still only on the horizon. Nevertheless, a prototype "reading" unit for selectively copying words for indexing and other purposes has been invented and built by this writer and is called the COPYWRITER (cf. Fourth Annual Report, Council on Library Resources, Washington, 1961, p. 30). This machine might be modified for use in character recognition machines for selected fonts (cf. Z. S. Harris, Intl. Conf. on Scientific Information, p. 949). Since one does know the particular typographical style used by publications regularly indexed, character readers can be built to accommodate these typographical styles (cf. J. Rabinow, *Character Recognition Machines*, 1961).

Chemical Names to Structural Diagrams

Assuming now that we have obtained some form of machine input either by character recognition or by manually creating a record in machine language, what do we wish to have done with this information?

Aside from the use that is made of the structural diagram by the chemist for naming chemicals systematically, and for calculating molecular formulas, one of the primary uses of the structural diagram is for communication. The organic chemist is able to comprehend a chemical most quickly when it is presented to him in the form of a structural diagram. This type of graphic presentation is absolutely necessary because the use of systematic nomenclature is frequently either too difficult or too time consuming. While it is theoretically possible to name any chemical by the Geneva system, it must be understood that this is far from true in practice. What actually happens is that certain complex configurations are assigned either a semi-systematic or trivial name. The chemist therefore overwhelmingly prefers the use of the structural diagram. However, in order to save space journals continue to use nomenclature extensively. One would therefore like to use the computer to convert chemical names back into structural diagrams.

Drawing Diagrams by Machine

At first glance the average chemist considers computer conversion of names to diagrams an impossible task. However, this is by no means the case. It is not true either in the sense of *recognizing* and understanding the chemical name itself nor in the sense that a machine cannot "*draw*". That structural diagrams can be drawn by machine is an accomplished fact. In two separate reports Opler and Waldo have shown that structural diagrams can be drawn by a computer. (A. Opler and N. Baird, Display of Chemical Structural Formulas as Digital Computer Output, *Am. Documentation* 10: 59 – 63, 1958) (W. H. Waldo and M. de Backer, Printing Chemical Structures Electronically. *Proc. International Conference on Scientific Information*, National Academy of Sciences, Washington, 1959, p.711–730). In fact, the diagrams drawn by Opler's computer were so realistic, few chemists would believe that it was not a photographic projection technique until they were shown exactly

how the illusion was created on the IBM 718 output tube. This particular computer output device has a television type raster. By energizing the appropriate combination of spots, one can obtain drawings of amazing complexity. If the drawings are examined from a distance, one cannot see the spaces between the spots, thereby creating the illusion that they are line drawings. This is basically the technique used in wirephoto facsimile. One can see such patterns of dots on the front page of the daily newspaper, as it is frequently necessary to transmit photos quickly, and the size of the dots consequently must be large and more perceptible to the naked eye. If the transmission rate is slowed down, one can increase the resolution to the point where the human eye cannot easily detect the presence of the dots. There is no question that we can mechanically display and print structural diagrams by computer.

Recognizing Chemical Names by Machine

If we are capable of drawing a structural diagram by machine, then we must determine whether we can indeed find a procedure for "recognizing" a chemical name in such a way that the computer can be properly instructed to draw the correct diagram. I first began to pursue this question years ago. Could a computable procedure be found for *recognizing* chemical names and what type of analysis would be required in order to find this procedure? A further question naturally concerned the design of an experiment which could be completed in a reasonable length of time, with a reasonable chance for success.

Upon examination of the complex computer programming required to reproduce a single *known* and coded chemical on a 718 display tube, it became quite apparent that to recognize a previously unknown, uncoded chemical was not a reasonable task for one person to accomplish. Opler estimated that at least ten man-years would be required *just* to write the necessary computer programs for displaying any type of chemical diagram after suitable linguistic analyses of organic chemistry had been performed (A. Opler, Private Communication 1959). For this reason it was ascertained how much effort would be required to produce conventional line formulas as e.g.

$$C{-}C{-}N(CH_3){-}C{-}C{:}C{:}O$$

To perform this feat, as in the case of drawing structural diagrams, this requires not only *recognition* routine, but also an extremely sophisticated *generation* routine, i.e. a procedure for generating the correct line-formula. This is further complicated by the fact that most general purpose computers do not have the typographical flexibility required for conventional line-formulas. Other methods of displaying chemicals as e.g. ciphers were also explored. A search of the literature and communication with the proponents of all well known notation systems indicated that such computer routines were not available. (G.M. Dyson and W.J. Wisswisser, Private Communication).

Calculating Molecular Formulas by Machine

Subsequently, I turned to the possibility of calculating the molecular formula. As has been stated above, the molecular formula is not only a widely used method of retrieving chemical information, it is also information that the chemist frequently needs in his laboratory work. In many situations it would not be necessary to draw a diagram if the molecular formula were available. Indeed, this is a very practical problem for every chemical publication or institution which prepares molecular formula indexes. The feasibility of preparing a program for generating molecular formulas seemed reasonable and provided a useful target for research.

While it was desirable to relate the study of finding a recognition routine to some usable output goal, the search for a recognition procedure might still have been undertaken anyhow. However, it is difficult to envision any recognition procedure which would not produce some type of usable output. Even a syntactic analysis of a sentence without regard to ultimate use does produce an output. In the case of chemical nomenclature, any output that results from a recognition routine has some value.

Having limited the scope of the output, it was then necessary to define and limit the recognition capabilities.

The Quagmire of Chemical Nomenclature

Organic chemical nomenclature is at first glance a horrible quagmire that could never be crossed by the most ambitious chemist. Naturally, the average chemist thinks first of the several million chemicals that have already been reported in the literature. There is almost an unlimited number of new chemicals that can be made. New combinations of atoms are uncovered every day. C. A. maintains a cross-reference file consisting of several hundred thousand entries. However, most people are unnecessarily discouraged by this state of affairs. It is necessary to differentiate the various facets of the problem of recognizing chemical names before one comes to the conclusion that it is a problem that is too hopeless to deal with.

There are three basic types of chemical names: (1) Trivial names, (2) Systematic names and (3) Semi-Systematic or Semi-Trivial names.

Trivial Names

The problem of handling trivial names must be dealt with in two parts: (a) names which are known prior to the computer analysis and (b) names which are entirely new. Tsukerman has properly called both types of trivial names "words-provocateurs" (opus cited, p. 4).

From the point of view of machine recognition of known trivial names there exists no problem. The storage of large dictionaries in computers is no longer a serious obstacle. With the improvement of so-called random access memory units we can expect to be able to look up items in large dictionaries quite rapidly at relatively low cost. While I would not underestimate the work involved in analyzing the thousands of trade names and other non-systematic names for chemicals, the problem of trivial names is indeed essentially trivial and of no basic interest to the linguist. This is primarily a problem of locating trade names and other synonyms by reference to standard compendia.

Legislation not a Solution

Similarly new trade names can be dealt with by non-linguistic methods. This may one day require legislative action, though it is extremely doubtful that we will see in our lifetimes the elimination of the practice of naming new chemicals biographically. You don't eliminate the use of terms like "*Richstein's Substance S*" by legislation. Rigid standards might make it very difficult for people to use such names in published journals. However, the use of trivial names or semi-trivial names is absolutely essential and *necessary* in chemistry and particularly in biochemistry. Unfortunately, the chemical structure of many chemicals is not completely known for many years. Many chemicals can only be identified by a molecular or empirical formula. The complete chemical *structure* may not be understood for many years as was the case with thousands of chemicals like *insulin*, *penicillin*, etc.

Systematic Names

Systematic names also fall into several categories. The word "systematic" is used very loosely to mean chemical names which are (a) named according to existing nomenclature systems or (b) named on the basis of a very prescribed list of basic terms. As the Geneva system has developed, the various commissions have tried to get chemists to rely on "systematic" nomenclature of the latter type, but this is not always easy. The I.U.P.A.C. rules as they stand today allow for so many exceptions in the selection of lexical items that it is incredible to think that all chemists will ever use it with 100% consistency. Indeed, in using CA or I.U.P.A.C. nomenclature one constantly faces the situation of having to name a chemical in a way which is completely foreign to the chemist. The rules are written primarily for the use of indexers. Consequently, the above distinction which is made by I.U.P.A.C. and by such Soviet authors as Tsukerman (opus cited) between so-called systematic and trivial names almost becomes meaningless. What is a trivial name to one chemist is a systematic name to another. If you are a steroid chemist then *androstane* is not a trivial name. It is amusing to observe that the 1957 Report (opus cited, p. 73) gives up any attempt to get chemists to name *androstane* as a derivative *cyclopentanophenanthrene*, the

more systematic description. It is equally ridiculous to call *cyclopentanophenanthrene* a systematic name when one could properly call the phenanthrene portion a derivative of *benzonaphthalene*. Once you are convinced, as I am, that the development of a truly systematic nomenclature for human communication is an impossible absurdity then distinctions between trivial versus systematic names also become absurd. If, on the other hand, one treats nomenclature linguistically chemical names can be classified as idiomatic or non-idiomatic expressions whose meanings can or cannot be computed from the meanings of the participating morphemes.

Treating Nomenclature as a Language

Most difficulties in dealing with nomenclature are due to the failure to recognize, in spite of its being a specialized jargon, that nomenclature is a sub-language of English (or whatever other language is involved). It displays many features of ordinary language. If the study of organic nomenclature is tackled as a linguistic as well as a chemical problem, then you avoid pitfalls such as the trivial-systematic dichotomy. If nomenclature is a linguistic problem then it seems reasonable to analyze the language of chemistry as you might analyze any other language. To completely describe a language is to write the grammar of that language.

Since I assumed chemical nomenclature to be a "language" with complexities or a range of complexities quite different than English or other natural languages, I was prompted to inquire how linguists might deal with such problems. I was further stimulated in this direction by the words of Bloomfield (Language, 1933) and Whorf (Language, Thought and Reality). This type of associative thought and further personal contact with linguists such as Harris inevitably focused my attention on the idea of treating organic chemical nomenclature as the structural linguist would treat a previously undescribed language.

While it was not possible for me to come to the linguistic laboratory with completely clean hands, having as a chemist acquired a general familiarity with chemical nomenclature systems, I was not uncritical of it. I have been reluctant to devote a great deal of time to the complete mastery of nomenclature because I feel that it has certain inherent limitations for communication and retrieval purposes.

In discussing organic chemical nomenclature, I have tried to indicate that as indexing problems have increased, nomenclature systems have tended to become geared more to the requirements of indexers rather than chemists or communicators. Naturally, both of these forces are constantly at work and the example I gave of the change in steroid nomenclature is one which indicates a case where the nomenclature experts had to revise systematic nomenclature to the facts as they already existed. Chemists had not followed the rules and the Commission could not overcome this fact in the in-between meetings. Between the first submission of the 1957 Report and its publication in

1960, there were over twelve thousand new steroid chemicals prepared. This is a fact from personal experience, as I examined that many steroid structures during the three years in question. In the face of such a rapid accumulation of new steroids, it is unreasonable to expect that chemists would do other than follow the principal-of-least-effort in naming chemicals. Even the layman has a good idea of what cholesterol is and it would be folly for scientific commissions to ignore the facts of natural linguistic growth. Creation of names cannot wait for the calling of annual committee meetings.

Designing Nomenclature for Machine Uses

On the other hand, if nomenclature systems can be designed both to help chemists communicate better and to index more consistently, why shouldn't nomenclature be designed so that it can be understood more easily by machines? In fact, it is not at all coincidental that elsewhere in this paper I have raised questions concerning the teaching of organic chemical nomenclature to humans. I suggest that a thorough re-examination of organic chemical nomenclature in terms of simplifying the process of analyzing chemical names by computer also would be most rewarding for teaching humans.

Certain practices are already noticeable in the naming of very complex chemical structures which appear to be accelerating this process anyhow. Chemicals are becoming so complex that chemists are finding it necessary to name them systematically but not in the I.U.P.A.C. or CA sense. This usage of existing terms does make sense to the reader and to the machine. The practice is increasing of adding substituents to the end of parent structures with intervening hyphens, without regard to the established I.U.P.A.C. rules of priority. For example, prefixes and suffixes are being used interchangeably. Most chemists could not care less whether substituents are listed in alphabetical order, by complexity, or by any other criterion. In fact, deviation from these complex ordering rules for multiple prefixes led to the formulation of a new method of filing steroids alphabetically. The system avoids absurdities which result from I.U.P.A.C.'s complex ordering rules [cf. E. Garfield, Steroid Literature Coding Project, *Chem. Literature* 12(3):6(1960)].

For example, it is the general rule in naming a chemical which has a particular function repeated to use the numerical prefix *di*. Thus one encounters *hexanediol* or more specifically *2,4-hexanediol*. If one files another chemical which is also a *hexanediol*, but which also contains an acid function as e.g. *2,4-dihydroxyhexanoic acid*, one obviously must file these two chemicals in entirely different places in an alphabetic scheme. However, the latter chemical could be called *2,4-diol-hexanoic acid* since *hydroxy* equals *ol*. Further simplification of the rules might produce *2-ol,4-ol-hexan-oic acid*. Not only is this easier to learn, it is certainly easier to analyze by machine.

Designing the Experiment

In designing the experiment and limiting its scope, I had to choose some portion of organic chemistry which was sufficiently large as to allow general conclusions to be drawn for chemical nomenclature in general. I chose acyclic chemicals as this class could be easily sub-divided if necessary. The experiment would still be reasonably complete so as to demonstrate the feasibility of tackling, by a team of linguists, chemists, and programmers, the entire domain of chemical nomenclature, especially the cyclics. The present análysis could be expanded to include and deal with more than 90% of the new compounds reported in the literature and a large percentage of the older literature by use of a relatively small number of additional morphemes such as *phen, benz, cyclo,* and other cyclic co-occurrences such as *aza, oxa,* etc. Thus, by a process of elimination the specific objective of my experimental program was established – to find a procedure for the machine translation of chemical names to molecular formulas.

One of the practical by-product results of this research has been to delineate a manual, algorithmic method of calculating the molecular formula of chemical names without resorting to structural diagrams. As I simulated the operations performed by the computer, based on the linguistic analysis, it became readily apparent that the procedure can be used manually. I am confident that most chemists will quickly learn and appreciate the simplicity of the method. One of the greatest values of trying to mechanize is that we are forced to look at a problem in a way that was hitherto difficult. The complete algorithm is summarized in Table V on page 30.

Another practical use of this new algorithm is found in the ability to train a non-chemist clerk to calculate a molecular formula from a chemical name.

Relationship between Nomenclature and Searching

A by-product of this study is the clearer understanding of the relationship between nomenclature and chemical searching requirements. When the computer analysis of the chemical name is completed, the parsed expression that results from the analysis could be used by the computer to perform very adequate *generic* as well as *specific* searches. If the chemists specifies the type of chemical in which he is interested in terms of morphemes instead of conventional chemical class names, generic searches become quite simple. Hence, a search for all *hexenols* becomes a search for all chemicals which contain the morpheme co-occurrence *hexen* and the morpheme *ol.* If he is interested in any six-carbon-chain-alcohol he need only specify the presence of *hex* and *ol,* where *hex* must be the carbon containing morpheme, not the multiplier morpheme as in *hexachlorooctane.*

While the computer program used in this research may be of interest to the reader (and for that reason is included here), it is only incidental to the general program of this research. The general requirements of the program, the basic approach, etc. are the pertinent factors. The specific methodology of particular computers is not of vital concern, though it is certainly an interesting exercise to work with a programmer. All of the actual Univac computer coding work was done in a relatively short time. Any large and several medium sized computers could have been used.

I personally prepared the Unityper tapes both for the input of the chemicals to be tested as well as the program. However, the actual Univac program coding was done by two University programmers, Dr. J. O'Connor and T. Angell. I wish to thank them both for this assistance. The coded Univac I program is omitted for this reason and comprises approximately 1000 code steps. However, the computer operation is described in general terms by flow diagrams in Tables VII to X.

While the study has been limited to acyclic compounds I was interested to explore just how difficult would be the transition to handling cyclic structures. A few cyclic morphemes were added to my testing procedure to simplify the selection of a random sample.

The exciting results of this side excursion over the border between the cyclic and acyclic compounds is that I have found cyclics to present no insurmountable obstacles. Certainly with sufficient, but reasonable manpower, it would be possible to resolve most of the ambiguities in the nomenclature, at least as far as calculation of molecular formulas is concerned. When we enter the realm of mechanically drawing structural diagrams then we are indeed faced with some grave problems in handling cyclics. We cannot ignore positional designations, which we can do in calculating molecular formulas. This is not because the syntactic problems of positional designations is itself difficult, which it is, but because there would appear to be no immediate solutions to the problem of resolving the use, by different chemists, of different systems of numbering well known ring systems. This would be more of a problem for older compounds published before the appearance of CA's Ring Index (Patterson, Cappell, Walker, *Ring Index*, Am. Chem. Soc., Washington, 1960).

Pattern Recognition Devices

This problem leads logically to another facet of the chemical information problem. Is it possible to find a method of "reading" structural diagrams. We have assumed all along that we would usually find our raw information in the form of printed chemical names. However, it is also true one has to deal with the printed structural diagram. Whether for the purpose of calculating a molecular formula or for naming the chemical systematically, a pattern-recognition device would be required in order to completely mechanize recognition. The National Bureau of Standards has been working on this problem using topological techniques. This is an exciting area of research, but we appear to be far from a solution to the problem.

Experiments with Cyclic Compounds

Preliminary experiments involving cyclic chemicals indicate that restricting the experiment to acyclic compounds does not affect the applicability of the procedure to cyclic structures. The greatest additional linguistic work is found, not in expanding from acyclics to cyclics, but from I.U.P.A.C. to less systematized nomenclature such as is used by *Chemical Abstracts*.

STRUCTURAL LINGUISTICS APPROACH TO CHEMICAL NOMENCLATURE

I shall outline below how a structural linguistic analysis of nomenclature differs from a non-linguistic approach. For example, the Soviet chemist Tsukerman (opus cited) uses the "syllabic" approach – a natural course for a chemist with good knowledge of nomenclature to follow. He thinks on terms of prefixes, suffixes, stems or roots, radicals, etc. On the other hand, the linguist studying nomenclature would not begin with the rule book of nomenclature, but rather with the actual discourse, the chemical names created by chemists. From the actual discourse he would discover the existing practices.

In principle, it is possible for a linguist to determine the morphemes of chemistry by interrogating an informant of that language. He can then apply the procedures of structural linguistic analysis to data obtained from the informant. The ultimate objective should be the most compact statement of the morphology.† Table I is a list of morphemes which I compiled for acyclic compounds. The word primary is used to indicate that these are the most frequently occurring – not that it is a preliminary list. In that case it would be a list of morphs.

Linguistic Forms and Their Environments

The basic approach of the structural linguist is to identify forms by examining the environments in which they occur. To obtain a description of a language one must examine a large corpus of that language. Allomorphs, morphemes, etc. are determined by a process of trial and error. Since a morpheme is a linguistic class it is essential that groups of occurrences be examined simultaneously if one is to determine that any particular sequence is or is not an occurrence of a morpheme.

†Since the phonemes of English chemical nomenclature were assumed to be the same as those used in normal discourse, it was not considered necessary to study the phonology. (There were very definite problems encountered by chemists in using Geneva nomenclature which could have been avoided if the conference had given some attention to phonetic transcription. Thus, the adoption of *yne* to differentiate acetylenes from *amines* became necessary later on. However, the phonetic identity of *ene* in *alkenes* and *ine* in *amines* is still a problem.) For the problem of translating chemical names to formulas phonology was not investigated. This does not mean that phonological studies are not germane to the problem of analyzing chemical discourse, as indeed they are. Such studies would help uncover ambiguities resulting from suprasegmental morphemes as e.g. in *dimethylphenylamine*.

In linguistics you cannot decide that a sequence is a morpheme unless you examine several utterances. Structural linguistics requires that linguistic forms be examined in *various* environments. In applying this technique to chemical nomenclature the procedure is facilitated by the existence of compendia such as Chemical Abstracts [cf. *Chemical Abstracts* 39,5867–5975(1945) for lists of frequently used radicals]. Here one finds occurrences organized by frequently occurring linguistic elements. It therefore becomes relatively simple to locate many occurrences of a particular element.

For example, in scanning a long list of chemical names you find the repetition of the segment *butyl* in names such as *butyl* chloride, *butyl*amine, di*butyl*amine, amino*butyl*decanol, *butyl*-aminohexane, etc. Preliminarily one can classify *butyl* as a morph. A *morph* is defined as a *putative* (tentative) *allomorph*. Further examination of more chemical names reveals the occurrence of *but* in *but*ane, *but*ene, *but*ynal, *but*anal, iso*but*ane, amino*but*enol, etc. In addition, one finds the occurrence of *yl* in hex*yl* chloride, hex*yl*amine, dihex*yl*amine, aminohex*yl*dodecanol, hex*yl*aminohexane, etc. On this basis the first trial, testing *butyl* to be a potential allomorph, is found to be in error. We find instead the morphs *but*, *yl*, *hex*, etc. If you ask an informant whether there is a difference in the reference meaning of *but* in each of these previous occurrences he will say there is no difference. The same will be true of *yl*. We can now proceed with further tests as to the morphemic character of *but*.

Suppose now the words *nembutal* and *nembutol* are discovered. One may call *nem* a morph. We assume that *but* in *nembutal* is a morph from the previous analyses. Then we check whether we can substitute any other morph for *nem* and we find we cannot. We also try to make a substitution for *but* in *nembutal* and we cannot. This would tend to indicate that the *but* in *nembutal* is not a morph. As additional evidence that *but* in *nembutal* is not a morph we may also ask the informant if there is a difference in the reference meaning of *but* in *nembutal* and *butane*. Should the informant not be able to express strong convictions about *but* in *nembutal* then one would rely on the formal evidence which definitely indicates that it is not the same morph as in *butane*. Thus we have dealt with the fortuitious occurrence of *but* in *nembutal*. We can now proceed with further tests as to the morphemic character of *but*.

To confirm that *but* is a morpheme we find that in most of its occurrences it can be substituted by *hex* as in *h*exane, *h*exene, *h*exanol, etc. In addition *but* can replace *pent* in *pentane*, *pentene*, *pentanol*, etc. We can now refer to each particular single occurrence of *but* as the morph and to the morpheme {c–c–c–c} when referring to the class of its occurrences. In this fashion we establish a preliminary list of morphemes.

Free Variation and Complementary Distribution

This list may be condensed by looking for allomorphs which occur either in free variation or in complementary distribution. In I. U. P. A. C. nomenclature there is no free variation. While

I.U.P.A.C. has eliminated free variation, it has not eliminated positional variance. We do find that *thi* and *sulf* are allomorphs of the morpheme {S}. *Thi* is in complementary distribution with *sulf*. In addition, the terminal *e* is in complementary distribution with the conjunctives *o* and *y*. These make up the morpheme {e, o, y}. *Ox* and *on* are also *allomorphs*, in complementary distribution, of the morpheme {ox, on}. *Ox* always occurs with the allomorph *o* of the preceding morpheme whereas *on* occurs with the allomorph *e*.

Co-occurrences in Systematic Organic Nomenclature

A list of co-occurrences in organic chemical nomenclature was compiled using the list of morphemes in Table I. The morphemes on this list were permuted with each other. From the total list of 1600 theoretically possible co-occurrences, 199 actual co-occurrences were determined. This was done by finding texts containing the co-occurrence or from personal knowledge of actual occurrences.

Lack of co-occurrence was further tested by using Prof. N. Rubin of the Philadelphia College of Pharmacy as an informant. We systematically went over the preliminary list of theoretical combinations. Many of the eliminations are based, not on their failure to occur in organic chemistry, but their failure to occur in acyclic compounds. Thus, combinations like *aza*, *oxa*, *thia*, *ole*, *inium*, *olium*, and *azol*, do in fact occur in chemistry, but only in cyclic structures. The classified list in Table II was compiled first. Then the alphabetic list in Table III was compiled to eliminate repetition.

TABLE I
LIST OF PRIMARY MORPHEMES FOR ACYCLIC ORGANIC CHEMISTRY

1. a	11. di	21. in	31. on**
2. acid	12. e*	22. iod	32. ox**
3. al	13. en	23. it	33. pent
4. am	14. eth	24. ium	34. sulf***
5. an	15. fluor	25. meth	35. tetr
6. at	16. hept	26. nitr	36. thi***
7. az	17. hex	27. o*	37. tri
8. brom	18. hydr	28. oct	38. y*
9. but	19. id	29. oic	39. yl
10. chlor	20. im	30. ol	40. yn

Asterisked items are allomorphs of one of the following morphemes:

* = {o, e, y}　　** = {on, ox}　　*** = {sulf, thi}

TABLE II. CLASSIFIED LIST OF CO-OCCURRENCES

a

hepta
hexa
octa
penta
tetra

acid

acid amide
acid halide
oic acid

al

alon
anal
enal
thial
ynal

am

amat
amid
amin
amon
anam
diam
enam
sulfam
thiam
triam
ylam

an

anal
anam
ane
ano
anoic
butan
ethan
heptan
hexan
methan
octan
propan

at

ate
nitrat

at

oat
sulfat

az

azid
azin
azo
azon
azox
diaz
hydraz
nitraz

brom

bromid
bromo

but

butan
buten
butox
butyl
butyn
ylbut

chlor

chlorid
chloro

di

dial
diam
diaz
dibrom
dibut
dichlor
dien
dieth
difluor
dihept
dihex
diim
diiod
dimeth
dinitr
dioat
dioct
dioic
diol
dion
diox

di

dipent
diprop
disulf
dithi
diyl
diyn

e

ane
ate
ene
ide
ime
ine
ite
one
yne

en

buten
enal
enam
ene
eno
enoic
enol
enon
enyl
enyn
ethen
hepten
hexen
iden
octen
penten
propen
thien
trien
ylen

eth

ethan
ethen
ethox
ethyl
ethyn
yleth

fluor

fluorid
fluoro

hept

hepta
heptan
hepten
heptyl
heptyn
ylhept

hex

hexa
hexan
hexen
hexyl
hexyn
ylhex

hydr

hydrat
hydraz
hydrid
hydrox
sulfhydr

id

amid
azid
bromid
chlorid
fluorid
hydrid
ide
iden
idin
idium
ido
idox
idyn
imid
iodid
nitrid
oxid
sulfid
ylid

im

ime
imid
imin
oxim
ylim

in

amin

in

azin
ino
inyl
sulfin

iod

iodid
iodo
iodox

it

ite
nitrit
sulfit

ium

idium
onium

meth

dimeth
methan
methox
methyl
trimeth

nitr

dinitr
nitrat
nitraz
nitrid
nitrit
nitro
nitroxo
nitryl

o

ano
ato
azo
bromo
chloro
eno
fluoro
hydro
ino
iodo
ito
nitro
oat
ono

o

oxo
oyl
sulfo
thio
yno

oct

octan
octen
octyl
octyn
yloct

oic

anoic
azoic
dioic
enoic
oic acid
onoic
thioic
ynoic

ol

anol
diol
enol
ol
olic
tetrol
thiol
triol
ynol

on

amon
anon
azon
dion
enon
onium
onoic
onyl
tetron
thion
trion
ynon

ox

ethox
hydrox
idox

ox

iodox
methox
nitrox
oxid
oxim
oxo
oxy
pentox
propox
triox

pent

dipent
pentan
penten
pentox
pentyl
pentyn
tripent

sulf

disulf
sulfam
sulfhydr
sulfid
sulfin
sulfit
sulfo
sulfon

tetr

tetra
tetrol
tetron
tetrox

thi

dithi
thial
thien
thio
thioic
thiol
thion
trithi
ylthi

tri

tribut

tri

trien
trieth
trihept
trihex
trimeth
trioct
triol
trion
triox
tripent
triprop
trithi
triyn

y

oxy

yl

butyl
enyl
ethyl
methyl
nitryl
oyl
pentyl
propyl
ylam
ylbut
ylen
yleth
ylhept
ylhex
ylid
ylim
ylmeth
yloct
ylpent
ylprop
ylthi
ynyl

yn

diyn
ethyn
idyn
propyn
triyn
yne
ynol
ynon
ynyl

TABLE III. ALPHABETICAL LIST OF CO-OCCURRENCES

1. acid amide
2. acid halide
3. amat
4. amid
5. amin
6. amon
7. anal
8. anam
9. ane
10. ano
11. anoic
12. anol
13. anon
14. ate
15. ato
16. azid
17. azin
18. azo
19. azoic
20. azon
21. azox
22. bromid
23. bromo
24. butan
25. buten
26. butox
27. butyl
28. butyn
29. chlorid
30. chloro
31. dial
32. diam
33. diaz
34. dibrom
35. dibut
36. dichlor
37. dien
38. dieth
39. difluor
40. dihept
41. dihex
42. diim
43. diiod
44. dimeth
45. dinitr
46. dioct
47. dioat
48. dioic
49. diol
50. dion
51. diox
52. dipent
53. diprop
54. disulf
55. dithi
56. diyl
57. diyn
58. enal
59. enam
60. ene
61. eno
62. enoic
63. enol
64. enon
65. enyl
66. enyn
67. ethan
68. ethen
69. ethox
70. ethyl
71. ethyn
72. fluorid
73. fluoro
74. hepta
75. heptan
76. hepten
77. heptyl
78. heptyn
79. hexa
80. hexan
81. hexen
82. hexyl
83. hexyn
84. hydrat
85. hydraz
86. hydrid
87. hydro
88. hydrox
89. ide
90. iden
91. idin
92. idium
93. ido
94. idox
95. idyn
96. ime
97. imid
98. imin
99. ine
100. ino
101. inyl
102. ite
103. ito
104. iodid
105. iodo
106. iodox
107. methan
108. methox
109. methyl
110. nitrat
111. nitraz
112. nitrid
113. nitrit
114. nitro
115. nitrox
116. nitryl
117. oat
118. octa
119. octan
120. octen
121. octyl
122. octyn
123. oic acid
124. ol
125. olic
126. one
127. onium
128. ono
129. onoic
130. onyl
131. oxid
132. oxim
133. oxo
134. oxy
135. oyl
136. penta
137. pentan
138. penten
139. pentox
140. pentyl
141. pentyn
142. propan
143. propen
144. propyl
145. propyn
146. propox
147. sulfam
148. sulfat
149. sulfhydr
150. sulfid
151. sulfin
152. sulfit
153. sulfo
154. sulfon
155. tetra
156. tetrol
157. tetron
158. tetrox
159. thial
160. thiam
161. thien
162. thio
163. thioic
164. thiol
165. thion
166. tribut
167. trien
168. trieth
169. trihept
170. trihex
171. trimeth
172. trioct
173. triol
174. trion
175. triox
176. tripent
177. triprop
178. trithi
179. triyn
180. ylam
181. ylbut
182. ylen
183. yleth
184. ylhept
185. ylhex
186. ylid
187. ylim
188. ylmeth
189. yloct
190. ylpent
191. ylprop
192. ylthi
193. ynal
194. yne
195. yno
196. ynoic
197. ynol
198. ynon
199. ynyl

The Problem of Syntactic Analysis in Organic Chemical Nomenclature

> In analyzing sentences "syntactic analysis" means: a procedure for recognizing the structure of a particular sentence taken as a string of elements. To state the structure of a string is to assign its words to word classes, to divide the word class sequence into substrings and to say what combinations of substrings are admitted. (Z.S. Harris, H. Hiz et al.: Transformations and Discourse Analysis. Univ. of Penna. Computing Center Annual Report. 1960, p. 43)*

By analogy, syntactic analysis of chemical nomenclature is the procedure for recognizing the structure of a particular chemical name taken as a string of elements (morphemes).

Since chemical names are often composed of long continuous strings of morphemes uninterrupted by spaces, hyphens, or brackets, it is necessary to set up a procedure for segmenting chemical words into morphemes. In some instances the chemist does this when he uses hyphens or spaces; however, in a name like *diaminopropylaminobutylhexene* the morphemes *di, amino, prop, yl, amino, but, yl, hex, ene* must be parsed as a continuous string of alphabetic characters. It is further necessary to establish the correct bracketing relationship between adjacent morphemes as e.g. between *di* and *amino* in *diaminopropylbutylhexene* on the one hand and *bis* and *aminopropylbutyl* in *bisaminopropylbutylhexene* on the other hand. In the latter case, the morpheme *bis* has a domain of operations quite distinct from that of its allomorph di. (The reader should remember that chemical morphemes are of two kinds: those which designate calculational values as e.g. *but* = C_4 and those which designate operations performed on them such as *di* = multiply by 2.)

In a comprehensive syntactic procedure for analyzing chemical nomenclature, all bracketing will be determined algorithmically. The computer procedure described in this study does it only in part. This was done to simplify the computer programming. I.U.P.A.C. rules on the use of brackets have been interpreted to mean they are always required when there is a possibility of ambiguity. In the above mentioned case *aminopropylbutyl* would be bracketed during the preparation of the input tape. This is perfectly legitimate use of the rules and I have assumed that all means to be tested are perfectly named. In a more ambitious recognition routine we would have to include additional syntactic procedures that would identify *hexene* as the parent function.

It is significant that neither I.U.P.A.C. nor C.A. accurately prescribe the limits of *bis*. In actual practice *bis* will apply to those morphemes which can be used as substituents and the implied bracketing will end before the "parent" morpheme modified by the substituents. Thus, in the case of *bis*-p-*methylaminophenylhydrazone* it might refer to $=N-N-(C_6H_4-NHCH_3)_2$ or

*For a more detailed treatment see Transformations and Discourse Analysis Project No. 15. Computable Syntactic Analysis. University of Pennsylvania, Dept. of Linguistics, 1959, p. 1.

$(=N-NH-C_6H_4-NHCH_3)_2$ and parentheses become essential. At the present time there appears to be no method for resolving such ambiguity except by pre-editing as was done in this experiment. (A useful function would be served if the computer determined whether *bis* was not followed by a paren. In that event the output would indicate possible ambiguity. In this case the name would not be considered to be well-formed.)

> "The successive words of each sentence are compared with the entries in a dictionary, and each is replaced by its dictionary equivalent, i. e., the class to which it belongs (e.g. verb.) The sequence of class names which now represent the sentence is scanned for class cleavage, i.e., cases where the word may belong to two or more classes (noun and verb, for example). A program is needed to decide to which class the word belongs in its grammatical context." (Harris, Z.S., Hiz, H. et. al opus cit., p. 44)

In the case of chemical nomenclature, the problem of classification would not appear to be as complex as in normal English discourse. However, in a comprehensive syntactic analysis compar- able operations would have to be performed. Otherwise we could not identify *nicotinoyl morpholine* and *pyridyl morpholinyl ketone* as synonyms. In the first case, morpholine is regarded as the parent structure. In the second case, *pyridyl morpholinyl ketone,* the ketonic function is considered the parent structure. This compound could also be regarded as a derivative of pyridine. (see p. 33)

If one seeks to recognize chemical names for the purposes of calculating from them their molecular formulas, then more elaborate forms of syntactic classifications of morphemes would not appear to be necessary. On the other hand, if the routine were designed so that one could both recognize chemical words and produce them according to I.U.P.A.C. rules, it would be very important to assign each morpheme to appropriate "syntactic categories," the sequences of which constitute well-formed chemical names. A cardinal principle of I.U.P.A.C. nomenclature is the selection of the principal functional group. A functional group is "one whose designation can be added at the end of the complete name of a compound without alteration to the name other than, sometimes, elision of terminal *e*." (R.S. Cahn, opus cited, p. 46). In this case, the choice would be quite clear. It must be named as a *ketone*, as this is the only element which is classified as a functional group.

Another important classification will be based on chain length. Hence it will be necessary to identify each member of the homologous series *meth, eth, prop, but,* etc. as such so that it will be possible to decide which of several that may appear in a name will take precedence. The principle of the *longest chain* can only be applied if one can array all members of this class which contribute chain length.

Yet another distinction is made on the basis of selecting chain lengths of greatest unsaturation. Consequently, the classification based on bonding, discussed below under *Bonding Morphemes* takes on even greater significance.

To carry the analogy further, chemical nomenclature also exhibits class cleavage i.e., cases where the morphemes may belong to two or more classes. An algorithm will therefore be required which determines for a particular grammatical context the class assignment of morphemes exhibiting class cleavage. This will be particularly true of expressions which must be classified both as regards chain length and/or functional group. Thus the common element *vinyl* (CH_2=CH–) contributes both to bonding, (unsaturation) as well as to chain length-two conflicting choices according to the circumstances.

Transformations in Organic Chemistry

The analogy between chemical names and normal sentences can be completed by showing that chemical synonyms exhibit transformational relationships similar to those exhibited by sentences. By using an appropriate notation we obtain the following transformations for the class of chemicals known as *diaryl ketones*, Ar_1–(C=O)–Ar_3, where Ar_2=Ar_1(C=O) and Ar_4=Ar_3(C=O).

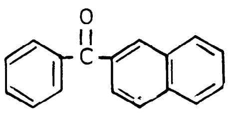
Ar_1*yl* Ar_3 *yl ketone* $\rightleftarrows$ Ar_2*oyl*Ar_3*ene* $\rightleftarrows$ Ar_1*ylcarbonyl*Ar_3*ene* $\rightleftarrows$ Ar_3*ylcarbonyl*Ar_1*ene* $\rightleftarrows$ $Ar_4$$Ar_1$*ene*

By using these transformations it is possible to generate the following list of perfectly good chemical names. Alongside each group of names is the corresponding structural diagram.

Ar_n	*A*	*B*	*C*	*D*	*E*
Ar_1 =	phen	pyridin	phen	pyridin	xyl
Ar_2 =	benz	nicotin	benz	nicotin	dimethylbenz
Ar_3 =	naphthal	morphol	morphol	naphthal	fluoren
Ar_4 =	naphthoyl	morpholenecarbonyl	morpholenecarbonyl	naphthoyl	fluorenecarbonyl

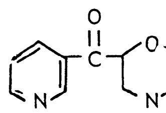
Group A

phenyl naphthyl ketone
benzoylnaphthalene
phenylcarbonylnaphthalene
naphthalylcarbonylphenene*
naphthoylphenene



Group B

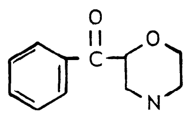
pyridinyl* morpholyl* ketone
nicotinoylmorpholene*
pyridinylcarbonylmorpholene
morpholylcarbonylpyridinene*
morpholenecarbonylpyridinene



Ar_1, Ar_2, Ar_3, and Ar_4 are class designations. The synonyms for any diaryl ketone can be named by these transformation rules. One can generate well-formed names simply by specifying the values for each Ar group. This means that if one specifies the

Group C

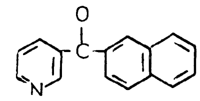
phenyl morpholyl ketone
benzoylmorpholene
phenylcarbonylmorpholene
morpholylcarbonylphenene
morpholenecarbonylphenene



*phenene → benzene (phen → benz)
pyridinyl → pyridyl (inyl → yl)
morpholyl → morpholinyl (yl → inyl)
morpholene → morpholine (ene → ine)
pyridinene → pyridine (inene → ine)
naphthalyl → naphthyl (alyl → yl)
fluorenene → fluorene (enene → ene)

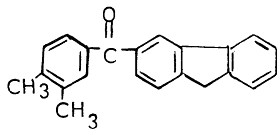
Group D

pyridinyl naphthalyl* ketone
nicotinoylnaphthalene
pyridinylcarbonylnaphthalene
naphthalylcarbonylpyridinene
naphthoylpyridinene



Group E

xylyl fluorenyl ketone
dimethylbenzoylfluorenene*
xylylcarbonylfluorenene
fluorenylcarbonylxylene
fluorenoylxylene



morpheme for Ar_1 and Ar_3 in Ar_1–(C=O)–Ar_3 a grammatically correct chemical name will be obtained by replacing Ar_1, Ar_2, etc. in the transformation equations. Prior knowledge of a correct chemical name is not required. In Table IV transformations for other chemical classes are illustrated. A thorough investigation of the transformations of chemical nomenclature would be a *sine qua non* for developing a procedure for the generation of standardized nomenclature. They are mentioned here only to complete the description of the analagous relationship that exists between syntactic analysis of normal English discourse and syntactic analysis of chemical nomenclature.

TABLE IV. TRANSFORMATIONS IN ORGANIC CHEMISTRY

Aldehydes RCH=O

R	b_n	R′	R$b_n$al	formyl Rb_ne	Rb_ne carboxaldehyde
pent	an		pentanal	formyl pentane	pentane carboxaldehyde
but	en		butenal	formyl butene	butene carboxaldehyde
prop	yn		propynal	formyl propyne	propyne carboxaldehyde

Esters R′COOR

			Ryl R′$b_n$oate	R′$b_n$oic acid Ryl ester	Ryl R′b_ne carboxylate
eth	en	pent	ethyl pentenoate	pentenoic acid ethyl ester	ethyl pentene carboxylate
hex	an	but	hexyl butanoate	butanoic acid hexyl ester	hexyl butane carboxylate
hept	yn	prop	heptyl propynoate	propynoic acid heptyl ester	heptyl propyne carboxylate

Alcohols R–OH

		Hydroxy Rb_ne	R$b_n$ol
pent	en	hydroxvpentene	pentenol
but	yn	hydroxybutyne	butynol

Ethers R–O–R′

			Roxy R′b_ne	Ryl R′$b_n$yl ether
prop	yn	but	propoxy butyne	propyl butynyl ether
hex	an	prop	hexoxy propane	hexyl propanyl ether
eth	en	prop	ethoxy propene	ethyl propenyl ether

(propanyl = propyl)

TABLE IV. TRANSFORMATIONS IN ORGANIC CHEMISTRY (continued)

Acids RCOOH

R	b_n	R′	Rb_noic acid	Rb_n carboxylic acid
prop	en		propenoic acid	propene carboxylic acid
but	yn		butynoic acid	butyne carboxylic acid

Amines R–N

	Amino Rane	Rylamine
eth	aminoethane	ethylamine
prop	aminopropane	propylamine

The Value of Structural Linguistics for the Study of Chemical Nomenclature

The linguistic approach to the study of nomenclature provides an insight to the inconsistencies that have slowly accumulated nomenclature's natural, historical development. Linguistic analysis enables one to uncover, in advance, ambiguities that will result from the imperfect rule book of chemical nomenclature. For example, linguistic analysis indicates the occurrence of the morphemes *di*, *meth*, and *oxy* and their co-occurrence in strings such as *dimeth*, *methoxy*, and *dimethoxy*. This finding uncovers another flaw in the accepted convention of organic nomenclature and renders existing organic nomenclature far from acceptable to the machine and the human. This realization might in turn lead to a readjustment in the rules of organic nomenclature which would stipulate that all numerical prefixes be followed by parentheses. This would make the job of recognition much simpler.

It should be made clear that this study by no means purports to be an exhaustive linguistic analysis of organic nomenclature. My remarks are intended as a summary of the methods that will undoubtedly be required should a completely exhaustive study of chemical nomenclature be undertaken. In that event one would encounter many additional ambiguities in nomenclature and many new interesting morpheme classes. Expanding the scope of the linguistic analysis in this way, e.g. would bring in the cyclic chemicals which account for the majority of new chemicals prepared today. It would also introduce the complexities involved in analyzing chemical names produced not only by the I.U.P.A.C. nomenclature but also by standard British and American nomenclature. This would introduce other complexities such as variations in spelling, use of different "trivial" words, etc. (cf. T. E. R. Singer, U. S. and British Index Entries, *Searching the Chemical Literature Advances in Chemistry No. 4*, Washington: American Chemical Society, 1951.)

The Value of the Study of Chemical Nomenclature to Linguistics

In a certain sense, the domain of chemistry represents a more strictly controlled experiment for testing linguistic procedures since there are a relatively small number of parameters. It is possible, as was done in this experiment, to vary the number of parameters according to the needs of the experiment. As one gains knowledge of the language, additional morphemes and syntactical relationships can be studied so as to determine their effect on previously established knowledge. Otherwise it becomes necessary to study the language in its entirety and by the time one has even located all occurrences in the language, the natural course of human events has changed some of the relationships. This is particularly true in chemistry, where there is now a very rapid change in terminology as a result of the rapid accumulation of chemical knowledge. Certainly from the point of view of historical linguistics, one can observe changes in chemical nomenclature take place in a period of ten years that might take hundreds in normal discourse.

AN ALGORITHM FOR TRANSLATING CHEMICAL NAMES INTO MOLECULAR FORMULAS

This dissertation reports the first successful procedure for direct translation of chemical names into molecular formulas.

To test the general validity of this procedure, an experiment was designed in which certain restrictions were placed on the input and output capabilities. These restrictions were made only to facilitate experimentation with an electronic computer. As will be seen, no such restrictions are necessary when the procedure is used by human translators. Indeed, it is one of the more significant aspects of this research that it is now possible, using this procedure, to train a non-chemist to calculate, quickly and accurately, molecular formulas. This could be done by completing, for the entire domain of chemical nomenclature, the dictionary of morphemes, idioms, homonyms, etc. that has been prepared for this experiment.

The dictionary of morphemes contains, for each morpheme, the calculational value and the pertinent operations of addition and/or multiplication for that morpheme or those which precede or follow. While the experimental dictionary of morphemes is small, it is not without interest to note that these morphemes account for a large percentage of all known chemicals. The morphemes that have been eliminated are those which are ordinarily considered to be non-systematic, i.e., trivial.

The procedure was tested on a Univac I computer. However, any medium-sized or large computer could be similarly programmed from the general flow diagram which forms a part of this work.

TABLE V

AN ALGORITHM FOR TRANSLATING CHEMICAL NAMES TO MOLECULAR FORMULAS

SUMMARY OF OPERATIONS FOR HUMAN TRANSLATION

1. Ignore all locants (1, a, N, etc.)
2. Retain all parens.
3. Replace all morphemes by dictionary value.
4. Resolve ambiguity of any penta-octa occurrences.
5. Place + after all morphemes except multipliers.
6. If there is + at far right of parenthesized term, place it outside right paren. If there is + at far right of name, always drop it.
7. Carry out all multiplications.
8. Calculate hydrogen using hydrogen formula: $H = 2 + 2n_C + n_N - n_X - 2n_{DB}$.

Ambiguity Rules

1. You cannot have two multipliers in a row unless separated by paren.
2. If either of the next two morphemes is alkyl ending, it is not multiplier
3. If not, it is multiplier.

TABLE VI

INVENTORY OF MORPHEMES USED IN THE EXPERIMENT

			Calculation Value						
Morpheme	Meaning	Example	p	C	O	N	S	DB	I
al	O=(H)	ethan*al*	–	–	1	–	–	1	–
amide	ONH_2	methan*amide*	–	–	1	1	–	1	–
amido	$C{=}O(NH_2)$	methan*amido*propane	–	1	1	1	–	1	–
amine	NH_3	methyl*amine*	–	–	–	1	–	–	–
amino	NH_2	*amino*butanol	–	–	–	1	–	–	–
*an	–	prop*an*ol	–	–	–	–	–	–	–
*ane	–	prop*ane*	–	–	–	–	–	–	–
bis	2X	*bis*(aminopropyl) amine	2	–	–	–	–	–	–
but	C_4	*but*ane	–	4	–	–	–	–	–
di	2X	*di*aminopropane	2	–	–	–	–	–	–
*en	=	but*en*ol	–	–	–	–	–	1	–
*ene	=	but*ene*	–	–	–	–	–	1	–
eth	C_2	*eth*ane	–	2	–	–	–	–	–
hept	C_7	*hept*ane	–	7	–	–	–	–	–
hepta	7X	*hepta*iodohexane	7	–	–	–	–	–	–
hex	C_6	*hex*ene	–	6	–	–	–	–	–
hexa	6X	*hexa*iodoheptane	6	–	–	–	–	–	–
hydroxy	OH	*hydroxy*ethanoic acid	–	–	1	–	–	–	–
*idene	=	butyl*iden*ehydroxyamine	–	–	–	–	–	1	–
imino	=NH	*imino*butanol	–	–	–	1	–	1	–

**bonding morpheme*

TABLE VI (cont.)

Morpheme	Meaning	Example	Calculation Value p	C	O	N	S	DB	I
iodo	I–	*iodo*ethanol	–	–	–	–	–	–	1
iodoso	IO–	*iodoso*ethane	–	–	1	–	–	–	1
iodoxy	IO–O–	*iodoxy*ethane	–	–	2	–	–	–	1
meth	C_1	*meth*ane	–	1	–	–	–	–	–
nitrate	$-N{=}O(O_2)$	methyl*nitrate*	–	–	3	1	–	1	–
nitrile	N≡	methane*nitrile*	–	–	–	1	–	2	–
nitrilo	N≡	*nitrilo*ethanol	–	–	–	1	–	2	–
nitro	N=O(O)	*nitro*butane	–	–	2	1	–	1	–
nitroso	N=O	*nitroso*butane	–	–	1	1	–	1	–
oate	O=(O)	ethyl pentan*oate*	–	–	2	–	–	1	–
oct	C_8	*oct*ane	–	8	–	–	–	–	–
octa	8X	*octa*iodooctane	8	–	–	–	–	–	–
oic acid	O=(OH)	pentan*oic acid*	–	–	2	–	–	1	–
ol	OH	pentan*ol*	–	–	1	–	–	–	–
one	O=	pentan*one*	–	–	1	–	–	1	–
oxo	O=	*oxo*pentanoic acid	–	–	1	–	–	1	–
oxy	–O–	meth*oxy*propane	–	–	1	–	–	–	–
oyl	O=	pantan*oyl* iodide	–	–	1	–	–	1	–
pent	5	*pent*ane	–	5	–	–	–	–	–
penta	5X	*penta*chloropentane	5	–	–	–	–	–	–
peroxide	–O–O	ethylmethyl *peroxide*	–	–	2	–	–	–	–
prop	C_3	*prop*yne	–	3	–	–	–	–	–
sulfate	$-O-SO_2-O$	methyl *sulfate*	–	–	4	–	1	–	–
sulfino	HSO_2-	*sulfino*propanoic acid	–	–	2	–	1	–	–
sulfinyl	–SO–	ethyl*sulfinyl*propane	–	–	1	–	1	–	–
sulfo	HSO_3	*sulfo*propanoic acid	–	–	3	–	1	–	–
sulfonyl	$-SO_2-$	methyl*sulfonyl*butane	–	–	2	–	1	–	–
tetra	4X	*tetra*iodobutane	4	–	–	–	–	–	–
tetrakis	4X	*tetrakis*(ethylamino)	4	–	–	–	–	–	–
thial	S=(H)	ethane*thial*	–	–	–	–	1	1	–
thio	–S–	methyl*thio*ethane	–	–	–	–	1	–	–
thiol	–SH	ethane*thiol*	–	–	–	–	1	–	–
thione	S=	propane*thione*	–	–	–	–	1	1	–
tri	3X	*tri*iodopropane	3	–	–	–	–	–	–
tris	3X	*tris*(aminopropyl)amine	3	–	–	–	–	–	–
*yl	–	buty*l*amine	–	–	–	–	–	–	–
*ylene	––	ethy*lene*diamine	–	–	–	–	–	–	–
yn	≡	buty*n*al	–	–	–	–	–	2	–
yne	≡	buty*ne*	–	–	–	–	–	2	–

**bonding morpheme*

Generalized Expression for the Molecular Formula

The result of my investigating the requirements for such an algorithm is the following simple generalized expression for a molecular formula in terms of morphemic analysis of its chemical name,

$$(1) \qquad \text{m.f.} = \sum_{p=1}^{j} p_j M_{i_n} + H$$

where P_j is the number of occurrences of morpheme M_{i_n}, i is the element (e.g. carbon, oxygen, nitrogen, etc.) and n is the number of occurrences of i in M. For chemicals which contain only carbon and hydrogen (Hydrocarbons) this expression becomes

$$(2) \qquad \sum_{p=1}^{J} p_j M_{c_n} + H$$

For chemicals containing the elements carbon, oxygen, nitrogen sulfur, and halogen the expression can be expanded as follows:

$$(3) \qquad \text{m.f.} = \sum p_j M_{C_n} + \sum p_j M_{O_n} + \sum p_j M_{N_n} + \sum p_j M_{S_n} + \sum p_j M_{X_n} + H$$

This expression covers all chemicals tested in this experiment.

Each of the terms in this latter expression can be expanded, as in the case of morphemes relating to carbon as follows:

$$(4) \qquad \sum p_j M_{C_n} = p_1 M_{C_1} + p_2 M_{C_2} + p_3 M_{C_3} + \ldots . \; p_j M_{C_\infty}$$

where M_{C_1} is the morpheme *meth*, M_{C_2} is the morpheme *eth* and all the other terms are the members of the homologous series C_1, C_2, C_3, ... C_∞. Each of the other terms in equation (4) is the summation of all morphemes which contribute to the value of that particular atomic element.

The value for hydrogen is found from the following expression

$$(5) \qquad H = 2\left[\sum M_C - \sum M_{DB} + 1\right] + \sum M_N - \sum M_X$$

M_{DB} is the special class of morphemes which contribute double bonds, and cyclics as e.g. *an*, *en*, *yn*, and *cyclo*.

Soffer's Equation for Molecular Formula

This expression is derived in part from Soffer's generalized expression for the molecular formula in terms of cyclic elements of structure. (M.D. Soffer, *Science*, **127**:880,1958).

(6) $$p = 1 + 1/2(2n_C + n_N - n_{H,X})$$

However, Soffer's equation does not take into account such elements as oxygen and sulfur, nor does it provide for chemicals such as quaternary ammonium compounds in a direct fashion. All such compounds are covered by the generalized expression pM_i. The case of quaternary compounds is particularly interesting, as its main morpheme constituent *ium* is classified by its DB value together with *en* and *yn*. *All of these* morphemes are 'bonding' morphemes. This is reasonable as in quaternary ammonium compounds nitrogen is in a pentavalent state and thereby contributes the equivalent of a double bond to trivalent nitrogen. For this reason, its DB value is minus one (−1).

Only One Language of Chemical Nomenclature

Aside from the utility of the algorithm for calculating molecular formulas, it is important to note that there really exists only one language of organic chemistry. It is a sub-language of English, but in spite of all the different "systems" available for naming chemicals, resulting in many synonyms for the same specific chemical, all of these systems draw on the same basic dictionary of morphemes. Two chemists may name the same chemical differently, but they will also be able to reconstruct the structural diagram of the chemical, and from it the molecular formula, with little or no difficulty. Upon cursory examination the chemical *2-(nicotinoyl)morpholine* might not appear to be the same as *3-pyridyl 2-morpholinyl ketone*, but drawing the structure of each, and calculating the formula would show that they are synonyms. Since there is in fact only one language involved, not several, the algorithm works regardless of the system used. It works equally well for Chemical Abstracts nomenclature as for I.U.P.A.C. nomenclature.

To illustrate the use of the algorithm a series of examples of increasing complexity are discussed. The first will illustrate the dictionary look-up routine, the second and third the use of multipliers and parenthesized expressions, the fourth a chemical requiring the use of an ambiguity-resolving routine. It is particularly interesting to observe that much of the complexity of computer programs for this type of analysis is due to the intricate steps required by the machine to recognize and deal with ambiguity. The human translator combines the ambiguity-resolving routine with the dictionary look-up routine quite easily.

First Example

As a first example consider the simple chemical name *methylaminoethane* in which there are no parenthesized terms, no positional designations (locants) or multiplier morphemes (coefficients).

Methylaminoethane is analyzed morphemically by the human translator as follows -- *meth, yl, amin, o, eth, an, e.* Each morpheme is assigned the following meaning by reference to the dictionary. Since these are the most frequently occurring morphemes in the language they are memorized in the first few minutes.

meth = C
yl = +
amin = N
o = +
eth = 2C
e = +

By the process of simple addition one obtains the partially complete molecular formula as 3C + N. When written in the conventional chemical subscript notation this becomes C_3N. It now remains to calculate the hydrogen.

$H = 2 + 2(3) + 1 - 0 - 2(0) = 9$ The complete formula is C_3H_9N

Second Example

As a second example let us consider the chemical

(3-(diethylamino)propyl)ethyl-3-amino-1,4-butanedioic acid

By a similar morphemic analysis this becomes

$(0-[2(2C) + N] + 3C) + 2C + 0 + N + 0 + 4C + 0 + 2(2\phi + DB)$ $\qquad \phi$ = oxygen

$(7C + N) + 6C + N + 4\phi + 2DB = 13C + 2N + 2DB = C_{13}N_2O_2 + 2DB$

and where $H = 2 + 2(13) + 2 - 0 - 2(2) = 26$ Final m.f. = $C_{13}H_{26}N_2O_4$

Third Example

As a third example consider *bis(bis[diethylamino]propylamino)butane.*

$2[2(2[2C] + N) + 3C + N] + 4C + 0$

$2[2(4C + N) + 3C + N] + 4C$

$2(8C + 2N + 3C + N) + 4C$

$16C + 4N + 6C + 2N + 4C = 26C + 6N = C_{26}N_6$

$H = 2 + 2(26) + 6 - 0 - 0 = 60$ and the m.f. = $C_{26}H_{60}N_6$

Fourth Example

Finally, consider the example of *hexanitrohexatriene.*

$6(N + 2\phi + DB) + 6C + 3\ DB$

$6N + 12\phi + 6DB + 6C + 3DB = 6C + 6N + 12\phi + 9DB = C_6N_6O_{12} + 9DB$

$H = 2 + 2(6) + 6 - 0 - 2(9) = 2$ and m.f. = $C_6H_2N_6O_{12}$

In this particular case the morphemic analysis is not as straightforward since there are several potentially ambiguous morpheme combinations.

Ambiguity and Principal of the Longest Match

The algorithm must account for the fact that the *hexan* in *hexanitro* is not the same as the *hexan* in a compound such as *nitrohexane* or for that matter the *hexane* buried in *hexatriene.* In the latter case the *hexa* in *hexatriene* is not the multiplier found in *hexanitro.* These ambiguities are resolved by a simple ambiguity-resolving sub-routine for the morphemes like *hex* (called *pent-oct* group in experiment). This consists of testing either one and/or two of the morphemes to the right of the ambigous *pent-oct* morpheme as to whether it is an alkyl ending (as e.g. *an, en),* a multiplier-morpheme (as e.g. *tri*) or a morpheme such as *nitro.* In order to understand how the computer procedure differentiates the *hexan* in *hexanitro,* it is necessary to explain the principal of the longest match which is used in the entire recognition procedure for assigning dictionary values to the morphemes. Since the human translator *learns,* he has no difficulty in making the differentiation.

In the experiment, it was found that the longest morpheme in the dictionary was eight letters long. For this reason, matching consists of examining the last eight letters of a chemical name first. In an expanded coverage of chemical nomenclature more letters would be matched as e. g., a morpheme such as *hentriacont,* meaning a thirty-one carbon chain. Consequently, in the example above, *hexanitrohexatriene,* the characters *xatriene* would be examined first. Since no match would be found for this combination of letters, the test would be continued with *atriene,* which again would find no match. There would be no match until *ene* was reached, at which point the last three letters of the name would be stripped and the procedure would continue with *ohexatri.* By a similar procedure, a match would be found for *tri.* Then we would match against *itrohexa* and we would find a match for *hexa.* (To simplify the procedure both *hex* and *hexa* are stored in the dictionary.) Simultaneously the *pent-oct* ambiguity-resolving routine would be called for, as each morpheme is always checked for membership in this list. The correct value of *hexa* in *itrohexa* having been determined, we would then move on to *exantro,* where we would encounter a match for *nitro,* leaving as the final residue, *hexa* which, of course, would go through the same ambiguity-resolving routine as the previous occurrence of this morpheme.

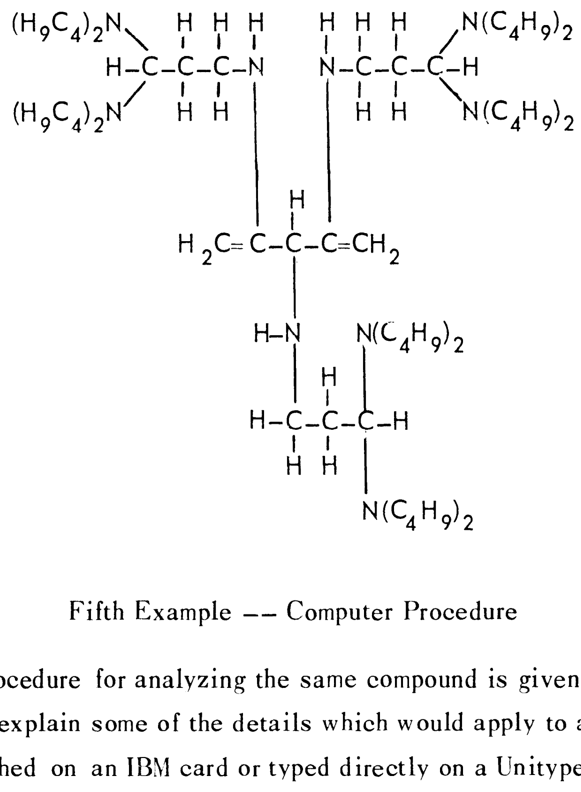
For the human translator, this procedure is by no means as complex, as one can readily perceive that *hexa* is followed by the very common morpheme *nitro* and subsequently by *tri.*

While the reader can apply the algorithm with no difficulty without a computer, the computer program may not be self-evident without reference to a specific example. For this reason, another example has been chosen which will test all of the steps in the program, including the general recognition program, dictionary look-up routine, *pent-oct* ambiguity- resolving routine, and formula

calculation routine. In order to test all boxes in the calculation routine it is necessary to select a chemical with several parenthesized expressions, i.e. nested parentheses.

Fifth Example -- Human Procedure

Consider the chemical *2,3,4-tris[3-bis(dibutylamino)propylamino]pentadiene-1,4*
Off computer the algorithm for this compound results simply in $3[2(2\ C_4 + N) + C_3 + N] + C_5 + 2$ DB. Carrying out the simple multiplications and additions gives a partial molecular formula of $C_{62}N_9 + DB_2$ and $H = 2 + 2(62) + 9 - 2(2) = 131$. m.f. $= C_{62}H_{131}N_9$. The structural diagram of this chemical is also shown to indicate how time-consuming it can be to go through the procedure of drawing such a diagram in order to calculate the molecular formula.



Fifth Example -- Computer Procedure

The computer procedure for analyzing the same compound is given below. Parenthetical remarks are made to help explain some of the details which would apply to all chemicals. The entire chemical name is punched on an IBM card or typed directly on a Unityper typewriter. The tape or card is then read into the main computer and immediately placed in a working storage unit. Working from right to left each character in the name is brought into the computer register one at a time and processed one at a time. The character in process at any instant is referred to as the *current character.*

Ignorability not Obvious Discovery

The first part of filtering each character consists of the test for 'ignorability', i.e. is it a character which cannot enter any look-up or other operations that will contribute to the molecular

formula. It is worth noting that ignorability of positional terms, i.e. locants in chemical names was no obvious discovery and had to be carefully checked for validity.

Current Character Processing

Since the first current character in processing our *pentadiene* example is an *e*, it is not ignorable. It will therefore not be possible to discuss how ignorable characters are handled until later in this example. Since the *e* is not ignorable it is then tested for being a paren and since it is not it is placed in a special storage unit called alpha storage. Immediately we ask whether there are eight characters in the alpha storage; since there aren't, we then test whether we have a sentinel character which signifies the end-of-name. In this experiment, the ampersand symbol was used for this sentinel.

Since we have not reached the end-of-name, the next character is taken out of working storage and processed in exactly the same way. This will continue, in this case, until we do have eight characters in the alpha storage *(ntadiene)*. At this point, we will process the alpha storage, initiating the dictionary match or look-up routine.

Dictionary Match Routine

The dictionary match routine will compare the contents of the alpha storage with the dictionary and will find a match for *ene*. Since this morpheme is not on the pent-oct list the morpheme *ene* will be placed in a special calculation and morpheme storage area along with its appropriate meaning. In this case it will be DB_1. The alpha storage will now be asked whether it is empty. Since it is not, all of the characters in alpha storage that remain will be shifted to the far right leaving *ntadi*. A match will be found for the morpheme *di* and it, too, will then be stored in calculation area. Numerical *multipliers* have a special code digit which is used during the formula calculation routine to differentiate them from *adders*.

Fully Processing Alpha Storage

The alpha storage is now shifted again. This time, when a match is sought for *nta*, there will be no such morpheme. Therefore, current character processing will continue until the first right paren is encountered. This paren will then cause the computer to check if alpha store is empty. Since it is not, the paren will be placed in a paren storage and the contents of the alpha storage will be *fully* processed which means that whatever characters remain in alpha storage must be one or more complete morphemes. In this case *penta* remains in alpha storage and it will go through the dictionary match routine. Since it is on the pent-oct list, it will also go through the pent-oct ambiguity-resolving routine.

Pent-Oct Ambiguity-Resolving Routine

Since the morpheme preceding *penta* is not an alkyl ending, the procedure then determines whether it is a numerical prefix. Since *di* is a numerical prefix, it is determined whether the next morpheme is an alkyl ending. Since *ene* is such an ending, *penta* will be stored in calculation area as would *pentane*, i.e. as a C_5 rather than as a multiplier. The ambiguity has been resolved. Current character processing is now resumed.

The eight characters *pylamino* will go into alpha storage and *amino* will be matched and placed in calculation area. Processing will continue and *yl* will also be matched. Processing will continue until the next right paren is encountered, at which point *prop* will be found in alpha storage, fully processed, and the paren will also be stored in the calculation area as a full word, since the alpha store will have been found to be empty. This was also done with the previous right paren when *penta* was processed. The procedure will continue similarly with *dibutylamino*, until the next paren (a left paren) is encountered. *Bis* will then be processed as a morpheme, the hyphen will be ignorable, as will the 3 and the second left paren will be encountered and placed in the calculation area. *Tris* will then be processed and the remaining characters ignored. When the end-of-name character is encountered, the formula calculation routine will be initiated. Determining whether a character is ignorable is done by a dictionary sub-routine, in which the computer compares each current character with a complete list of ignorable characters consisting of the integers 1 to 8, hyphen, comma, prime, and colon. The presence of an ignorable character will always indicate the beginning or the ending of a portion of the name which can be processed independently of the other portions.

Computer Calculation Routine

The calculation storage area of the computer now contains the following sixteen calculation words. Each morpheme is followed by its appropriate additive or multiplicative value. Note that parens also stored as separate calculation words.

Word	*Value*	*Word*	*Value*	*Word*	*Value*	*Word*	*Value*
1. tris	3(9)	5. di	2(9)	9.)	---	13.)	---
2. (	---	6. but	C_4	10. prop	C_3	14. penta	C_5
3. bis	2(9)	7. yl	---	11. yl	---	15. di	2(9)
4. (	---	8. amino	N	12. amino	N	16. ene	DB

The first portion of the calculation routine disposes of parentheses and multiplying operations. The first word *tris* is a multiplier, so it is then determined whether the next word is a left paren, which it is. The computer now starts counting left and right parens. We again ask if the next word is a paren. Since it is not, but it is a multiplier, *bis*, multiplication is not yet carried out.

Since the next word is a left paren, the count of left parens will increase to two. However, since the registers for left and right parens are not yet equal, the next word is examined. Since *di* is not a paren, but is a multiplier, it, too, will be ignored. The next word is *but*. Since it is not a numerical prefix, it will be multiplied by the multiplier *tris*. The same will occur for *yl*(7), *amino*(8), *prop*(10), *yl*(11), and *amino*(12) as they are all contained within the parens covered by *tris*(1).

When the right paren following the last *amino*(12) is encountered, the left and right paren registers will be equal. This will signal computer to return to the word immediately following the first left paren – *bis*(3). A similar process will now be followed which will result in multiplying *but*(6), *yl*(7) and *amino*(8) by two. When the paren following the first *amino*(8) is encountered, the computer will be referred back to the first *di*(5). Since it is a multiplier, is not followed by a paren, *but*(6) will be multiplied by two.

Before proceeding, the computer checks whether the last word in calculation area has been reached. Since it has not, *yl*(7) will be processed and ignored as will *amino*(8), right paren(9), *prop*(10), *yl*(11), *amino*(12), right paren (13), and *penta*(14) which had been found, during the ambiguity-resolving routine, to be C_5.

Since *di*(15) is a multiplier the morpheme *ene*(16) is multiplied by two. Since it is the last calculation word, the paren and multiplication operations are completed. All parens and multiplier calculation words are now replaced by zeros. The computer then adds the contents of these registers which now looks as follows:

	Word	*Value*		*Word*	*Value*		*Word*	*Value*		*Word*	*Value*
1.	tris	000	5.	di	000	9.	)	000	13.	)	000
2.	(	000	6.	but	$C_4x3x2x2=C_{48}$	10.	prop	$C_3x3=C_9$	14.	penta	C_5
3.	bis	000	7.	yl	000	11.	yl	000	15.	di	000
4.	(	000	8.	amino	$Nx3x2=N_6$	12.	amino	$Nx3=N_3$	16.	ene	$DBx2=DB_2$

The totals are taken and give a partial molecular formula of $C_{62}N_9DB_2$. The hydrogen calculation is performed using the equation $2 + 2n_C + n_N - n_X - 2n_{DB}$. In this case it is 131 giving a final formula of $C_{62}H_{131}N_9$.

The computer will now test for experimental purposes whether the calculated formula agrees with the formula calculated manually and stored with the original data.

Hydrogen Calculation

The calculation of hydrogen is by no means a simple straightforward or obvious task. There are two ways of solving the problem. There is the method described in this dissertation which

derives form Soffer's formula and there is the standard procedure used by chemists. To give the reader an idea of the difficulties of using the conventional method, he is referred to the complex chemical diagram shown on page 36, where the fifth example is discussed. It is obvious that the brute force method of counting 131 hydrogen atoms is likely to generate errors. To duplicate the brute force method of calculating hydrogen by an algorithm is not only difficult but also uneconomic in terms of computer time.

The assignment of computational values (semantic mapping) to a relatively small list of morphemes which also accounts for hydrogen, would at first glance, appear to be a rather trivial task. However, here one must depart from morphology and take into consideration the rules of chemical bond formation. For example, the term *methyl* consists of two morphemes *methyl* and *yl*. This is one of the most commonly occurring terms in organic chemistry and has a calculational value of CH_3. It is invariably CH_3. On the other hand, *propane* is $CH_3CH_2CH_3$. However, *methylpropane* is not merely the summation of the values for methyl and propane. In adding the *methyl* group, one must replace one of the hydrogen atoms on the *propane* nucleus giving a structure $CH_3CH(CH_3)CH_3$ more commonly called isobutane. If in compiling a dictionary of morphemes, we assign the values usually associated with the morpheme, then we must incorporate very sophisticated rules based on a knowledge of chemical formation. The problem increases in complexity when dealing with names containing morphemes such as *oate*, where a chemical reaction is implied as between an acid and an alcohol to form an ester. For example, the simple chemical *ethyl ethanoate (ethyl acetate)* is not the addition of $C_2H_5+C_2H_6+O_2$. The formula for this chemical is $C_4H_8O_2$ since an ester is formed from the combination of an alcohol and an acid with the elimination of a molecule of water.

The linguist is prompted to ask whether one has the right to include hydrogen value in the semantic mapping of morphemes such as *meth*. The morpheme *meth* will always contribute one carbon atom to the molecular formula, but it does not always contribute three atoms of hydrogen. It is not at all obvious, even to the chemist, how one resolves the problem of hydrogen calculation. It is well known that the number of hydrogen atoms in a saturated hydrocarbon is derived from the relation $2N_C+2$ where N_C is the number of carbon atoms. However, the average chemist has no systematic method of quickly solving for hydrogen.

Soffer (opus cited) provides a more sophisticated statement of the relationship between the number of cyclic configurations in a chemical and its molecular formula. I had previously used Soffer's formula in checking the accuracy of several thousand formulas. However, it did not occur to me immediately that it could be modified and used as a means for obtaining the hydrogen value directly. It was observed that each of the terms in Soffer's equation could be replaced by a term representing a morpheme, i.e. a group of allomorphs, particularly the "bonding" morphemes contributing to 'cyclic' configuration. Then it was possible to simplify the syntactic rules for each morpheme.

The value of this approach is more apparent if one considers an example in which hydrogen is determined by the previous method of first identifying the 'parent' structure in a chemical name. The parent morpheme is frequently an alkane ending such as *ane*. The chemical *4-hydroxy-3-heptanone* is derived from *heptane*. You calculate its molecular formula by starting with C_7H_{16}, the molecular formula of heptane. The morpheme *one* adds an oxygen atom and subtracts two hydrogen atoms.

For *hydroxy* you add another atom of oxygen. *Hydroxy* contains one additional hydrogen atom, but this is balanced by the loss of one H atom in adding the *hydroxyl* substituent. This procedure works quite well for chemicals with straightforward substitution of one functional group for hydrogen. However, it breaks down in more complex cases. By confining one's dictionary to morphemes in which hydrogen is excluded and calculated after all other calculations are performed, a more straightforward procedure is possible.

Thus, the assignment of 'meaning' is conditioned by the syntactic methods that are employed for analyzing the chemical name and for generating the correct molecular formula. However, once the new approach is chosen, one must analyze each morpheme a little more closely. It is not sufficient to know that nitro is NO_2. It is necessary to learn that it is one nitrogen atom attached to two oxygen atoms, in which, one of the attachments is by a double bond. The presence of this double bond affects the total hydrogen content of the molecule. It therefore must be recorded in the dictionary along with the remaining semantic information.

Having recorded the semantic value of each morpheme, it is further necessary to provide rules for distinguishing between the homonyms which occur in systematic nomenclature. Thus, there is a class of numerical prefixes which unfortunately are ambiguous with morphemes for alkanes. For example, *pent* may be additive, as in a chain of five carbon atoms, such as pentatriene or it may be a multiplier as in pentachlorohexane. This situation is not unlike the problem of syntactic analysis of English text, in which, one finds two words in a sentence which are part of the same verb, but are separated by an intervening word, e.g. a split infinitive.

TABLE VII. GENERAL PROGRAM FOR CHEMICAL NAME RECOGNITION

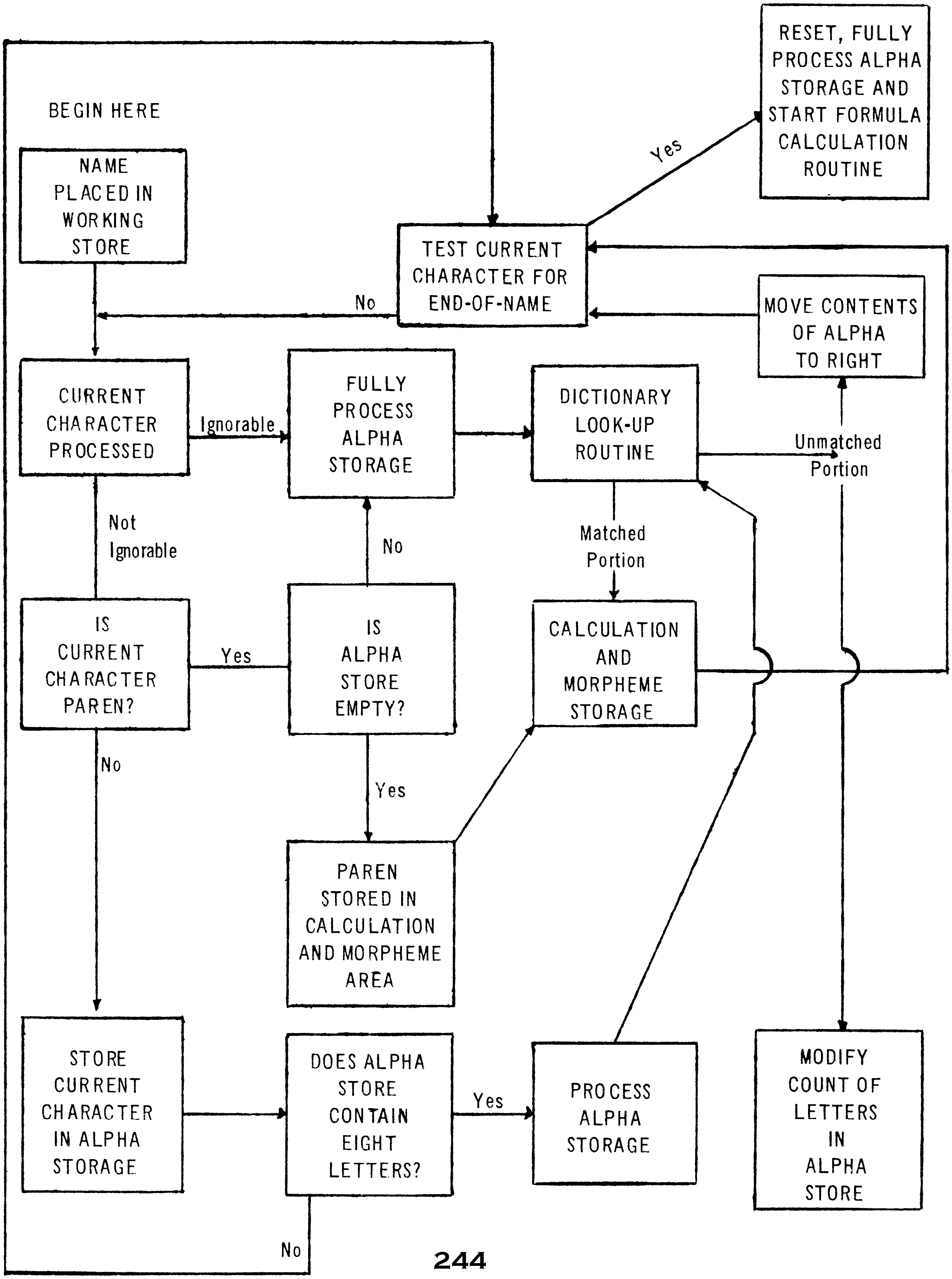


TABLE VII
CHEMICAL NOMENCLATURE ANALYSIS
COMPUTER CALCULATION OF MOLECULAR FORMULAS
GENERAL PROGRAM DESCRIPTION

1. Chemical name is typed on Unityper. Only chemical names of sixty characters or less are allowed, to simplify programming. Sixty characters are stored in five Univac words.

2. Chemical name is placed in working storage. (Left-to-right in the name is equivalent to top-to-bottom in storage.)

3. Processing of name starts with bottom character in working storage, i.e. character on the far right of chemical name.

4. Determine whether the current character is ignorable, i.e., a dash (hyphen), number, prime, comma, or delta (space).

5. If it is, then ignore it and fully process* contents of alpha storage.

6. If it is not ignorable character, determine if current character is paren.

7. If current character is a paren, store it in calculation area of storage, unless alpha storage already contains something, in which case, store the paren in paren storage and fully process* alpha storage.

8. If it is not a paren and also not ignorable, then store it in alpha storage. Continue processing until eight characters are stored in alpha storage. This is determined by counting characters as they go into alpha storage.

9. Find a "match" for the contents of the alpha storage, i.e. from the morpheme dictionary, look up value of morpheme in alpha storage. This might be the entire eight letters or just two letters, but no less than two letters, otherwise there is error signal.

10. When the match is found, enter the calculation value of the morpheme in the next available storage location of the calculation storage and the morpheme itself in the morpheme area.

11. Move any remaining unmatched portion to the far right in alpha storage. At the same time this will change the count of the number of letters in alpha storage.

*Fully process alpha storage means that whatever alphabetic characters are in alpha storage will be examined so as to identify the morpheme(s) involved. After finding a match for the right end of alpha storage the remainder will be shifted and similarly processed. However, "fully" process cannot be used if alpha storage processing was started as a result of 8 count.

2. Keep on examining more characters in name until there are again eight characters in alpha storage.

3. Continue the process until all characters have been placed in storage. When end-of-name signal (&) is encountered, computer will know that processing of all characters has been completed.

TABLE VIII. CHEMICAL NOMENCLATURE ANALYSIS

DICTIONARY LOOK-UP ROUTINE

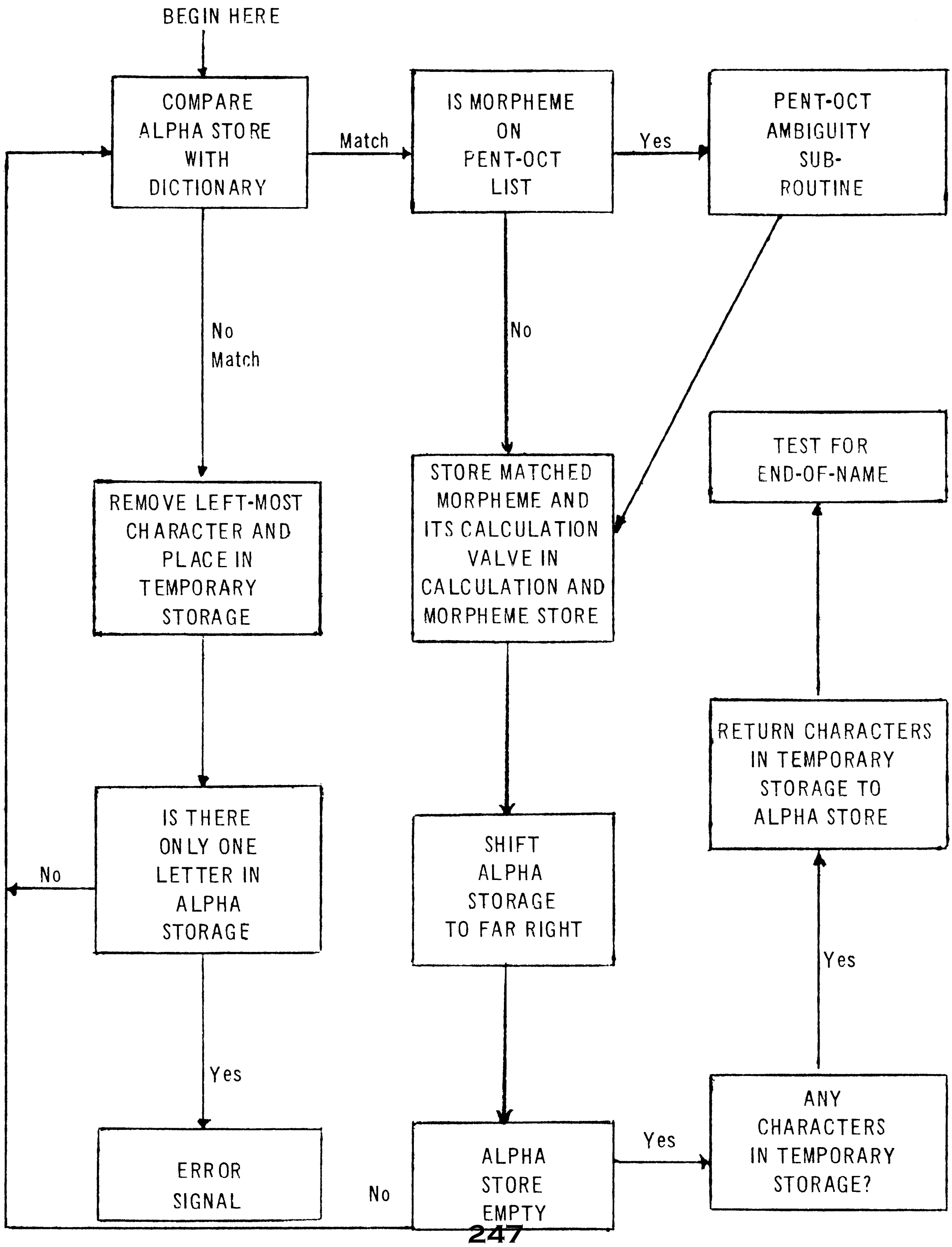


TABLE VIII
CHEMICAL NOMENCLATURE ANALYSIS
DICTIONARY LOOK-UP ROUTINE

1. The longest morpheme match is looked for first. The characters in alpha storage are compared to all morphemes in dictionary.

2. If no match is found, left-most character is dropped and matching process begins again. In this way *thial* is matched before al.

3. Before matched morpheme is stored in calculation area, it is checked for being in pent-oct group of homonyms.

4. If the morpheme is found to be in pent-oct group, then a special ambiguity-resolving routine is initiated.

5. If morpheme is not pent-oct, it is placed in calculation and morpheme storage.

6. If alpha store is not empty, it is shifted to far right and process begins over.

TABLE IX. PENT-OCT AMBIGUITY RESOLVING ROUTINE

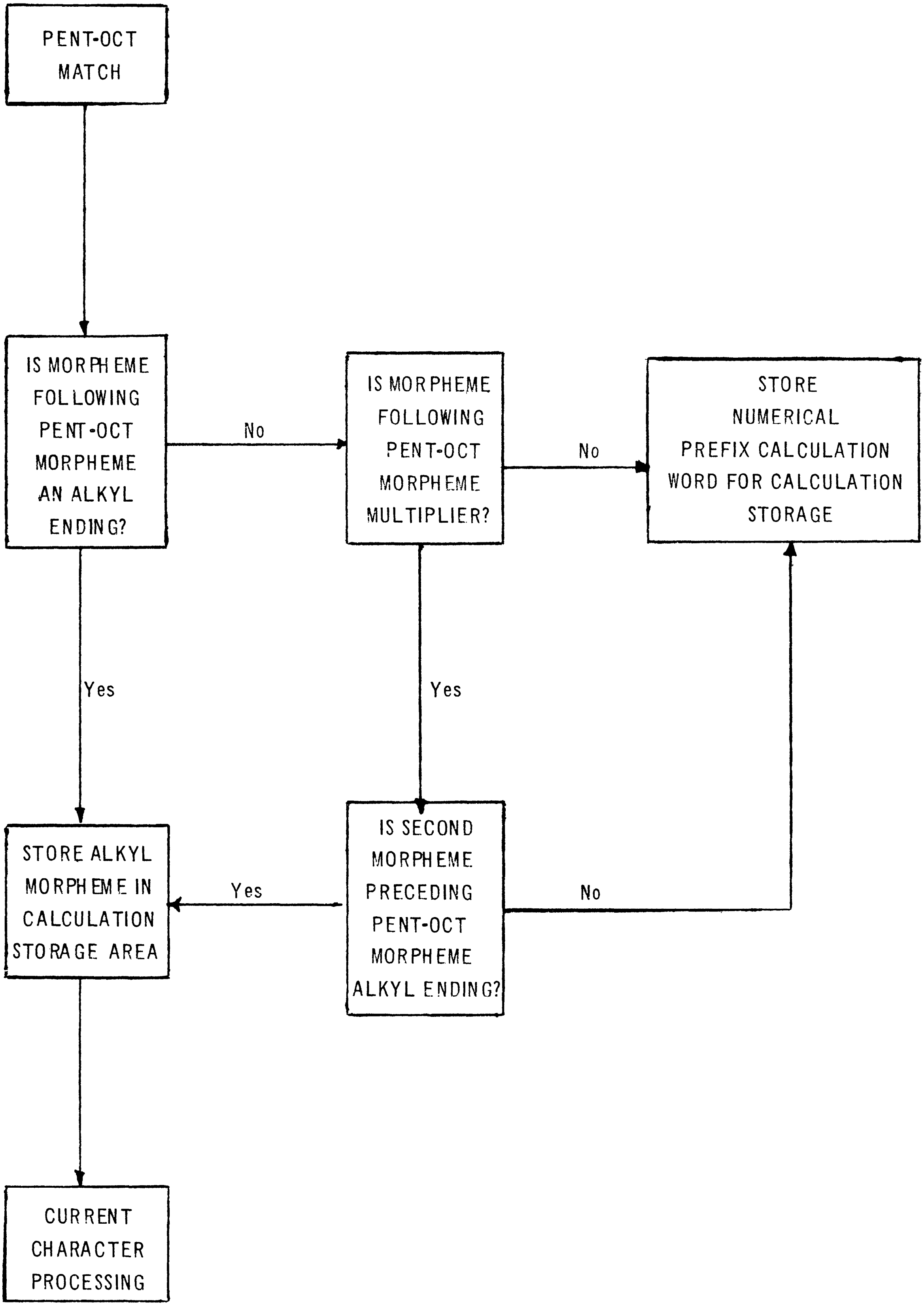


TABLE X. MOLECULAR FORMULA CALCULATION ROUTINE

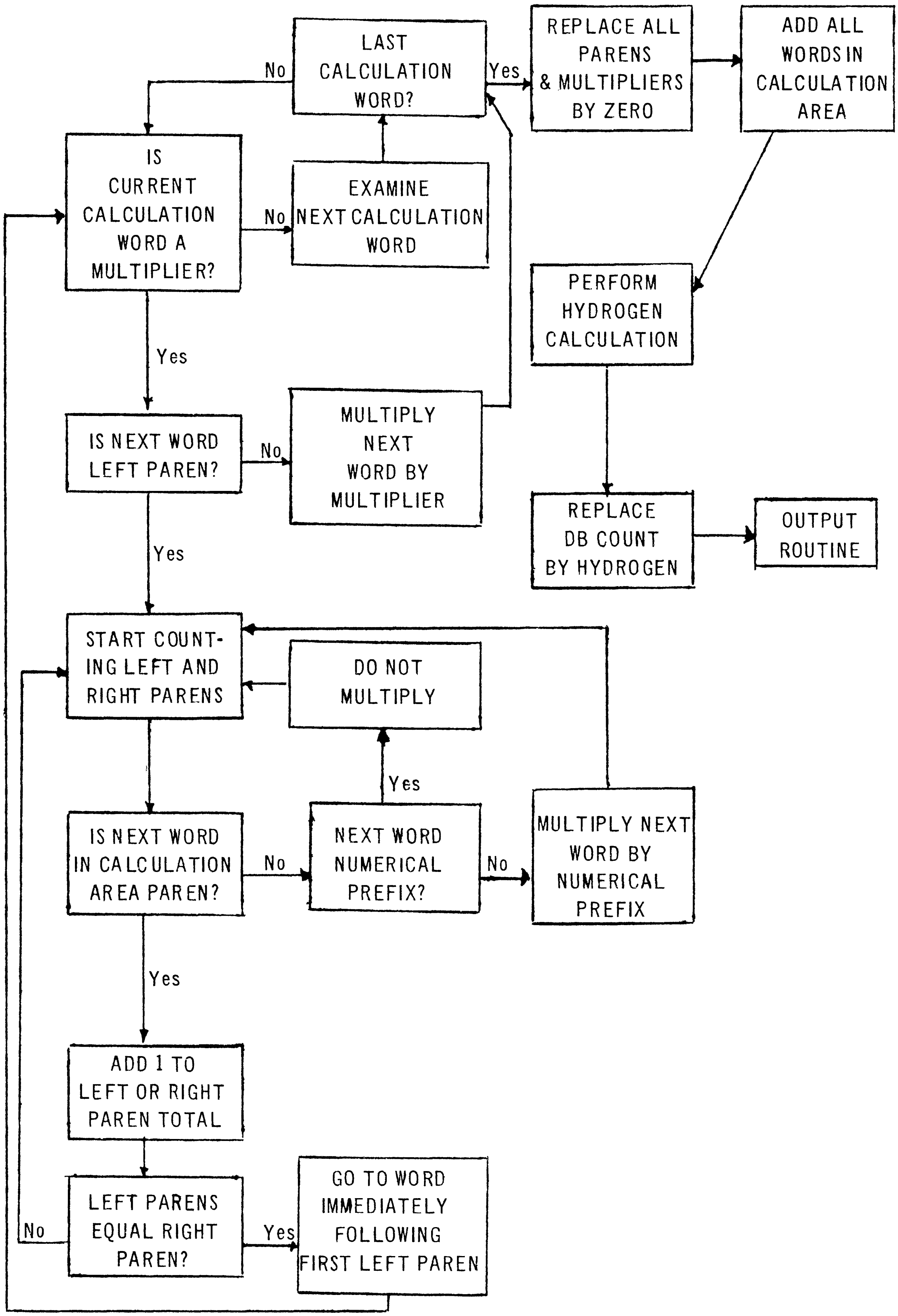


TABLE X
MOLECULAR FORMULA CALCULATION ROUTINE

1. Find a word which is a multiplier.
2. If the next word in calculation area is not a left paren, multiply it by the multiplier and continue looking for other multipliers.
3. If the next word is a left paren, starting keeping totals of left and right parens counting this as first left paren.
4. Examine each successive calculation word.
5. If it is not a paren, multiply it by the multiplier, unless it is a numerical prefix.
6. If it is a paren, add one to the left and right paren totals.
7. End process as soon as the left and right paren totals are equal.
8. Now go back to the word immediately following the first left paren and continue looking for multipliers. So process all multipliers in the calculation area.
9. Replace every paren word and every multiplier word in the calculation area by zero. Now add all words in the calculation area.
10. This gives preliminary total formula count. Now calculate H.
11. Replace DB value in preliminary total formula with the calculated H value.

The calculational value of each morpheme is stored as a twelve character number in which each successive pair of numbers represents iodine, double bonds, oxygen, nitrogen, sulfur and carbon. When the final calculation is made, the double bond position is replaced by the hydrogen count. Hence, nitro is stored as +0/01/02/01/00/00, iodo +1/00/00/00/00/00/ and methyl + 0/00/00/00/01. Since the Univac requires one character for sign, no formula containing more than nine iodine atoms can be tested in this equipment.

Sampling Method

The manual translation procedure was tested on dozens of chemicals. Some of these were deliberately selected as presenting difficulties. Others were randomly selected. For example, the deliberately chosen names included several that contained pent-oct ambiguous morphemes as e.g. *hexanitrohexadiene*. Others involved complex nesting of parens. The fifth example shown previously is typical of these.

Certain chemicals found in C.A. indexes did not calculate correctly for hydrogen. The morpheme *imino* was found to be used by C.A. quite inconsistently. A basic principle of good nomenclature is that structure and name should correspond. Names should not be based on the origins of compounds. A C.A. example is *1,1'-(ethylenediimino)di-2-propanol* which by I.U.P.A.C. nomenclature is *1,2-bis(2-hydroxy-propylamino)ethane. C.A.* violates the principle that each morpheme should consistently represent the same substituent. This name was omitted from the test as it would give wrong hydrogen count. In any computer program that would attempt to cover all systems, including C.A.'s, *imino* would require a special ambiguity-resolving routine.

When I was satisfied that I had deliberately tested all the morphemes in the dictionary a random sample of chemicals was obtained. This was done by asking a clerk to check the first chemical at the top of each column in the 1958 Subject Index to *Chemical Abstracts*. He was told to keep scanning until a name was located which could be obtained from the morphemes on the test list. This required the elimination of hundreds of chemicals which contain cyclic morphemes rather than acyclic. The following illustrate some of the samples located.

CA Page No.	*Molecular Formula*	*Chemical Name*
37	C_5H_9NO	2-hydroxy-2-methyl-butyronitrile
38	$C_5H_{10}N_2S$	2-amino-4-(methyl-thio)butyronitrile
39	$C_5H_{10}O_2$	4-methoxy-2-buten-1-ol
40	$C_5H_{11}NO_3$	methylnitro-2-butanol
52	$C_6H_9N_3$	3,3'-iminodipropionitrile
56	$C_6H_{11}NO_3$	6-amino-4-oxo-hexanoic acid
57	$C_6H_{12}N_2O_4$	2,3-dimethyl-2,3-dinitrobutane
58	$C_6H_{12}O_2S$	3-(propylthio)-propanoic acid
59	$C_6H_{13}NO$	4-dimethylamino-2-butanone
71	C_7H_9NO	3,4-dimethyl-2-oxopentenenitrile
73	$C_7H_{10}O_2$	3-ethylidene-2,4-pentanedione
80	$C_7H_{15}NO$	1-dimethylamino-2-methyl-3-buten-2-ol
80	$C_7H_{15}NO_3$	[bis(2-hydroxyethyl)amino]-2-propanone

I have intentionally listed the compounds for pages 37, 38 and 52 even though they do not come under the purview of this experiment. In spite of my instructions, it was apparently difficult for the person taking the sample to note that the *yro* and *ion* were not on the list of morphemes.

One other interesting example that had to be eliminated from the computer testing, but not the human testing, was the following: *N*–[(2-[*1,1-dimethyl-2-propynyloxy*]*ethoxy*)*methyl*]*diethylamine*. The use of the *N* as a locant was not anticipated in preparing the computer program. It would have to be added to the list of ignorable characters.

An additional random sample was taken from the *Merck Index*. This was done by taking a continuous series of chemicals in the cross-reference index. This gave quite a scattering of page numbers as is shown below:

Page	*M.F.*	*Chemical Name*
178	$C_4H_{11}N$	1-aminobutane
53	$C_4H_9NO_2$	4-aminobutanoic acid
738	$C_9H_{22}N_2$	2-amino-5-diethylaminopentane
1013	$C_2H_7NO_3S$	2-aminoethanesulfonic acid
315	C_2H_7NS	2-aminoethanethiol
4	$C_2H_6N_2$	α-amino-α-iminoethane
666	$C_5H_{11}NO_2S$	2-amino-4-methylthiobutanoic acid

Selections were still made that could not be handled by the experimental dictionary as e.g. sulf*onic* acid. Further, the use of *alpha(a)* as a locant was not anticipated for the computer program, though it could be easily added to the list of ignorable characters.

As a further test of the algorithm several chemists were asked to coin names that might be difficult to handle.

A few of these were 3,7-dimethyl-2,6-octadienal, 3,3′-dithiobis(2-aminopropanoic acid) and 1,4-bis(methanesulfonoxy)butane. The latter is not covered by the experimental dictionary.

Debugging

As a further test of the procedure, fifty of the randomly selected compounds were tested on the Univac I. The so-called debugging procedure uncovered dozens of coding mistakes in the computer program which had to be traced meticulously. Apparently the first twelve deliberately chosen compounds were well selected, as the computer went into loops on each one until the bugs were eliminated.

A More Significant Test

It is obviously important that the absolute validity of the algorithm be proven by more extensive sampling. However, the chemist knows intuitively, once he has used it, that it will work. When it fails, he will find ambiguities in the nomenclature as in the case of *imino.*

Of further importance was an informal test to verify the claim that chemists first draw a diagram in order to calculate molecular formulas. For this reason, I showed about a dozen chemists example *five* and asked each to calculate the formula. Invariably he would draw a diagram. All were surprised that the calculation could be reduced to such a brief algorithm. This confirms my belief that the algorithm can be an extremely useful teaching device. It certainly can be helpful to the indexer. Most graduate organic chemists already have memorized a large enough number of morphemes to calculate quite quickly without learning anything but the DB rules. This includes the more complex cyclic structures. Every steroid chemist knows that the steroid nucleus is C_{17} so it is quite simple for him to calculate steroid formulas no matter how complicated the name may be.

*See page 36.

The Bonding Morphemes

One particularly interesting product of this research has been the more precise definition of a class of so-called *endings* or suffixes.for which, surprisingly enough, the chemist has no generic term. During the entire course of this investigation, difficulties were encountered in keeping programmers aware of the difference between an *alkyl* group and an *alkyl* or *alkane* ending. Neither of the latter two are accurate. Open chain hydrocarbons have the generic name *alkanes. Alkyl* is the generic term for hydrocarbon *radicals.* To use these terms to describe *alk-yl* suffixes is quite inaccurate. Furthermore, this does not associate all of the suffixes that can now be properly grouped in what I shall call the *bonding morphemes.* The members of this morpheme class are morphemes such as *ane, ene, yne, idene,* and *ium* since they contribute to the DB value of the chemical. In the pent-oct ambiguity-resolving routine, it would be more accurate to describe the operation in terms of bonding morphemes as the *alkyl* morphemes are really this group of bonding morphemes. It is interesting that to learn the algorithm completely from memory, the chemist need only learn the correct DB values for all morphemes, some of which may not be obvious. The chemist does not usually think of a triple bond as being two double bonds. Thus the DB value for *nitrilo, cyano, diazo,* and *yne* are the same i.e., DB_2.

Conclusions

I believe there are a number of important conclusions that can be drawn from this work. There can be no doubt that one can calculate molecular formulas from chemical nomenclature. The

grammatical work that remains to be completed is still quite large, but it does not appear to be so large that a group of chemists and linguists would have any difficulty completing it within a reasonable length of time. Further, if a computer is at their disposal, there are many shortcuts that could be taken in the analyses. If the grammatical work is expanded to include the type of syntactic analysis in which each morpheme is described as a part-of-speech, i.e. classified according to its membership in various grammatical categories, then it is quite possible to foresee a machine procedure which could generate standardized names. The same would be true of displaying structural diagrams. In fact, the latter problem is less sophisticated, in that there are a relatively small number of topological arrangements required in chemistry. The programming difficulties would arise in making the appropriate additions to the diagrams for substituent atoms. In the case of *nicotinoyl morpholine*, there is only one topological configuration, the hexagon, but the replacement of carbon by nitrogen and/or oxygen in the pyridine and morpholine rings requires considerable programming ingenuity. This work would be aided by the grammatical analyses.

It would also be safe to conclude that by similar procedures, one could analyze the chemical terminology of other languages and by establishing the transformations of that language, arrive at a method for translating chemical terminology quite easily. For certain languages, such as Russian, the work involved should not be very great as one can already, simply by transliteration of Russian nomenclature, understand most of the chemical names.

The linguistic approach to chemistry, i. e. chemico-linguistics holds great promise for chemist and linguist alike. For the chemist, it can mean greater precision in teaching and understanding nomenclature and even chemical classification per se. It is not improbable that a suitably written grammar of organic chemistry could help postulate new and interesting chemical structures. On the other hand, I believe that the field of chemistry offers the linguist a useful model for the study of normal discourse. If the problems of chemical nomenclature cannot be resolved by linguistic analysis, then I suspect that normal discourse will be much too formidable an obstacle. Certainly if we are to find methods of analyzing chemical texts for indexing and other purposes, we cannot expect better than a 50% resolution of the indexing problem in chemistry. More than 50% of the effort that goes into indexing chemistry is in the analysis of chemical names. A large part of the work that is done in reading chemical documents involves the recognition of dozens of chemical names, both new and old. We will have reaped a very poor harvest if we are able to describe the text of a chemical article grammatically without a corresponding ability to deal with the problem of synonymy.

TABLE XI

RANDOM SAMPLE OF CHEMICALS TESTED ON COMPUTER PROGRAM

butane = C_4H_{10}
2-aminoethanol = C_2H_7NO
1,4-bis(ethylamino)butane = $C_8H_{20}N_2$
1,3,5-heptatriene = C_7H_{10}
1,2,3,4,5,6,7-heptaiodooctane = $C_8H_{11}I_7$
2-[(3-aminopropyl)ethylamino]ethanol = $C_7H_{18}N_2O$
1,4-bis[bis(3-diethylaminopropyl)amino]butane = $C_{32}H_{72}N_6$
1-methylsulfonylbutane = $C_5H_{12}O_2S$
2-methylpropanedioic acid = $C_4H_6O_4$
1-propanethiol = C_3H_8S
3-pentanethione = $C_5H_{10}S$
1,6-dinitrohexane = $C_6H_{12}N_2O_4$
2,5-diaminohexanedioic acid = $C_6H_{12}N_2O_4$
4-oxo-heptanedioic acid = $C_7H_{10}O_5$
1-dimethylamino-2-methyl-3-buten-2-ol = $C_7H_{15}NO$
1-ethylamino-2-methyl-3-buten-2-ol = $C_7H_{15}NO$
2-(hydroxymethyl)-2-propyl-1,3-propanediol = $C_7H_{16}O_3$
3-ethyl-2-amino-3-pentanol = $C_7H_{17}NO$
8-hydroxy-6-octene-2,4-diynenitrile = C_8H_5NO
2-propenyl-2-pentenoic acid = $C_8H_{12}O_2$
2-ethylidene-3-methyl-1,5-pentanediol = $C_8H_{16}O_2$
2-nitro-2-pentyl-1,3-propanediol = $C_8H_{17}NO_4$
3-diethylamino-2-methyl-1-propanol = $C_8H_{19}NO$
5,5'-oxybis(2-methyl-2-pentanol) = $C_{12}H_{26}O_3$
1,1-diiodo-2-nitro-1-pentene = $C_5H_7I_2NO_2$
pentyl nitrate = $C_5H_{11}NO_3$
2,5-diiodo-hexanedinitrile = $C_6H_6I_2N_2$
1-aminobutane = $C_4H_{11}N$
4-aminobutanoic acid = $C_4H_9NO_2$
2-amino-1-butanol = $C_4H_{11}NO$
2-amino-5-diethylaminopentane = $C_9H_{22}N_2$
2-aminoethanethiol = C_2H_7NS
2-amino-5-hydroxypentanoic acid = $C_5H_{11}NO_3$
1-amino-1-iminoethane = $C_2H_6N_2$
2-amino-4-methylthiobutanoic acid = $C_5H_{11}NO_2S$
3-methyl-1-pentyn-3-ol = $C_6H_{10}O$
1,3-butadiene = C_4H_6
bis(hydroxyethyl)amine = $C_4H_{11}NO_2$
2,2-bis(hydroxymethyl)-1,3-propanediol = $C_5H_{12}O_4$

TABLE XI (cont.)

2-ethoxyethanol = $C_4H_{10}O_2$
dimethylenimine = C_2H_3N
3,7-dimethyl-2,6-octadienal = $C_{10}H_{16}O$
3,3′-dithiobis-(2-aminopropanoic acid) = $C_6H_{12}N_2O_4S_2$
1-iodo-3-iodomethyl-5-methylheptane = $C_9H_{18}I_2$
1,4-diiodo-2-(methylbutyl)-butane = $C_9H_{18}I_2$
methylsulfonylethane = $C_3H_8O_2S$
(2-hydroxyethyl)-4-hydroxymethyl)-3-propyl-1,6-hexanediol = $C_{12}H_{26}O_4$
methylthiopropane = $C_4H_{10}S$
1-(propylsulfinyl)butane = $C_7H_{16}OS$
ethylsulfinylethane = $C_4H_{10}OS$
ethanamide = C_2H_5NO
butanediamide = $C_4H_8N_2O_2$
methylthiopropane = $C_4H_{10}S$
nitrosobutane = C_4H_9NO
ethylmethyl peroxide = $C_3H_8O_2$
iodosoethane = C_2H_5IO
iodoxypropane = $C_3H_7IO_2$
sulfopropanoic acid = $C_3H_6O_5S$
ethanethial = C_2H_4S
trichloromethane = $CHCl_3$
tetranitromethane = CN_4O_8
1-nitro-1,1,2,2,2-pentachloroethane = $C_2Cl_5NO_2$
hexachloroethane = C_2Cl_6
1,1,2-trichloroethane = $C_2H_3Cl_3$
octachloropropane = C_3Cl_8
propylnitrate = $C_3H_7NO_3$
1,1,1,3,3-pentachloro-2,3-dinitro-2-trichloro-methylpropane = $C_4Cl_8N_2O_4$
4-chloro-3-butyn-1-ol = C_4H_5ClO
2-methyl-1,2-dinitropropane = $C_4H_8N_2O_4$
1,4-diamino-2-butanone = $C_4H_{10}N_2O$
1,3,3,4,4-pentachloro-2-methylcyclobutene = $C_5H_3Cl_5$
penten-4-ynol = C_5H_6O
4,5,5-trichloro-4-pentenylamine = $C_5H_8Cl_3N$
dimethylcyclopropane = C_5H_{10}
chloropentanol = $C_5H_{11}ClO$
pentachlorobenzene = C_6HCl_5
2-aminochloronitrophenol = $C_6H_5ClN_2O_3$
benzenediol = $C_6H_6O_2$
2,6-dichlorocyclohexanone = $C_6H_8Cl_2O$
1,1,1-trichloromethyl-3-penten-2-ol = $C_6H_9Cl_3O$
1-cyclopentene-1-methanol = $C_6H_{10}O$
chlorocyclohexane = $C_6H_{11}Cl$
2-amino-4-butyl-6-nitrophenol = $C_{10}H_{14}N_2O_3$
(1-cyclohexen-1-yl) butanone = $C_{10}H_{16}O$
2-phenyl-2,4,6-cycloheptatrien-1-one = $C_{13}H_{10}O$
7-(2,4,5-trichlorophenoxy)heptanoic acid = $C_{13}H_{15}Cl_3O_3$
ethyl 2-cyano-5-phenyl-2,4-pentadienoate = $C_{14}H_{13}NO_2$
7-(4-dimethylaminophenyl)-2,4,6-heptatrienenitrile = $C_{15}H_{16}N_2$
1-3-bis(aminophenoxy)-2-propanol = $C_{15}H_{18}N_2O_3$
4,6-dibutyl-3-methyl-2,4-dinitro-2,5-cyclohexadien-1-one = $C_{15}H_{22}N_2O_5$
2,4-dimethyl-3-octyl-2-cyclopenten-1-one = $C_{15}H_{26}O$
2-nitro-4-phenyl-1-naphthol = $C_{16}H_{11}NO_3$
1-(nitrophenyl)-4-phenyl-2-butene-1,4-dione = $C_{16}H_{11}NO_4$
2-(naphthyl)-2-cyclohexen-1-one = $C_{16}H_{14}O$
diphenyl-3-butynol = $C_{16}H_{14}O$

APPENDIX

I.U.P.A.C. Organic Chemical Nomenclature
A Summary of Principles Including a Detailed Example of its use both in Recognition and Generation of Systematic Names

In summarizing the basic principles of I.U.P.A.C. organic nomenclature for the non-chemist, emphasis has been placed on didactive explanations that will help in the recognition of the meaning of chemical names, rather than complete rules for the generation of names. The latter would require a knowledge of chemistry at least to the extent of understanding structural diagrams. This is not even necessary for the acyclic straight chain hydrocarbons covered in this experiment. Therefore, by following the instructions for naming hydrocarbon derivatives, a non-chemist should have no difficulty creating perfectly reasonable and accurate names for simple chemicals. For the more complex molecules, I suspect he would have no more and possibly less difficulty than the chemist who comes to the subject with certain preferences based on his knowledge of chemistry.

Punctuation

Commas are used between numerals which refer to identical operations as in *1,2,3-tribromohexane.*

Colons are used between groups of numerals for similar but distinct operations as in *1,2:5,6-diisopropylidenesorbitol.*

Numerals should be placed immediately in front of the syllables to which they refer as e.g. *2-bromohexane* rather than *bromo-2-hexane; hexan-2-ol* rather than *hexanol-2.* However, in the U.S. 2-hexanol would be rather commonly encountered. The numeral designates the number of the carbon atom in the longest chain of carbon atoms contained in the chemical. The variations in the use of numerals are legion and present a major obstacle to comprehension, especially in French and German literature. In some systems Greek letters are used instead of numerals. Amino acids are popularly numbered this way as in *β-hydroxyalanine,* which is also *2-amino-3-hydroxypropanoic acid* also known as *serine.*

Order of Substituents

Prefixes are arranged in *alphabetical order.* The atoms and groups are alphabetized first and the multiplying prefixes are then inserted as in: *2-bromo-1-chloro-hexane; 4-ethyl-3-methyl-hexane;* and *1,1,1-trifluoro-3,3-dimethylpentane.*

Elision

The terminal *e* is elided before a vowel of an organic suffix, but not in cases where the following letter is a consonant. *Propane* becomes *propanone; hexan-2-one* becomes *hexane-2,3-dione.*

Hyphens

These are used between two identical letters to avoid ambiguity as in tetra-amino. The Chemical Society uses hyphens also when partial names end in a voiced vowel or *y* as e.g. in *amino*-derivative, *thia*-compound, *methoxy*-group, but not after a consonant in such places as methyl derivative, amide group. In English, chemical words do not end in vowels.

Parentheses

Parens are used when necessary to clarify the limits of operations but not unnecessarily. If a string of morphemes is contained in parens which is preceded by a numeral, this means that the entire parenthesized expression is a substituent of a parent structure. For example, *1-(4-amino-2-ethylphenyl)-butanol* means that the entire expression *4-amino-2-ethylphenyl* is attached to the first atom in a four carbon *(but)* chain. The word *mono* is understood but rarely used. However, if the chemical were *1,2 bis-(4-amino-2-ethylphenyl) butanol* the entire parenthesized expression would be multiplied by two, i.e. it occurs at both the first and second carbon atoms in the chain C–C–C–C.

Terminology

Parent is a very ambiguous term in chemical nomenclature, especially when one considers the rules for deciding which morpheme in a name shall be considered the parent morpheme. However, no matter what name is chosen the *parent* morpheme refers to that group of atoms to which all other groups of atoms in the molecule are attached. Thus *benzene* is the parent in *nitrobenzene* and *ethane* is the parent in *ethanol.* This term no longer has any chemical significance which, at one time, was true when chemicals were named on the basis of the shortest chain length.

Group or radical. Any group of atoms commonly occurring together is called a group or radical. Most of these are single morphemes but some are pairs of morphemes. CH_3 is a *methyl* group consisting of the morphemes *meth* and *yl.* However, OH is the hydroxy group.

Function or Functional Group

A *functional group* is a group of atoms which defines the mode of activity of a chemical. The hydroxy group gives alcoholic properties to an alcohol. A ketone owes its properties to the oxygen atom which is doubly bonded to carbon. The distinction between what is functional and what is not is frequently difficult to make, but is an important artefact in naming chemicals regardless of how they act.

Types of Names

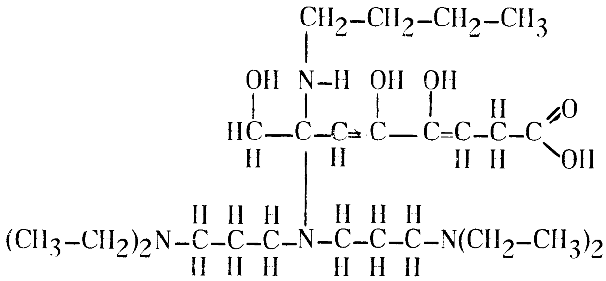
There are several types of names encountered in systematic nomenclature aside from the previously discussed *trivial* and semi-systematic names. There are names which involve *substitution,* where one hydrogen atom is replaced by a group or another element, as in *pentanol,* where one hydrogen atom is replaced by the hydroxy radical or group. There are *replacement* names, where one atom such as sulfur replaces another, such as oxygen, as for example *propanol* and *propanethiol,* which are respectively C–C–C–OH and C–C–C–SH.

A *subtractive* name involves the removal of specified atoms as e.g. in aliphatic names ending in *ene* or *yne* exemplified by *hexene* or *hexyne* where hydrogen atoms are removed by the creation of double or triple bonds between carbon atoms -- C–C–C–C–C=C.

There are other types of names such as *radicofunctional,* a name formed from a radical and functional class name such as *ethyl alcohol; additive* names such as *styrene oxide,* conjunctive names such as *naphthaleneacetic acid,* and fusion names such as *benzofuran* and other cyclics. However, in this brief survey, we will be primarily concerned with systematic names, i.e. names "composed wholly of specially coined or selected syllables, with or without numerical prefixes" [cf. I.U.P.A.C.: *Nomenclature of Organic Chemistry.* London: Butterworths, 1958(p. 4)].

What's In a Name?

When the layman sees a chemical name like *7-bis(3-diethylaminopropyl)amino-7′butylamino-4,5,8-trihydroxyoct-3,5-dienoic acid,* he probably wonders how it is possible for chemists to make sense out of it. The structural diagram for this chemical is



However, chemical names are surprisingly simple to understand and a large number of those made can be derived from a relatively short list of morphemes, such as that which was used in my experiments (see Table VI).

Principal Functional Group

The first thing that must be done in understanding, or for that matter in creating a chemical name is to "*seek out the functional groups.*" (Cahn, opus cited p. 43.) The *senior,* i.e. *principal functional group* sets the whole pattern of nomenclature and numbering. Unfortunately this is not always as simple as it sounds, though in the example above it is quite simple. It is worth noting that among others Degering (cf. *Organic Chemistry — An Outline of the Beginning Course Including Material for Advanced Study*; 6th Ed. New York: Barnes & Noble, 1957) completely avoids a discussion of this problem of naming so-called *complex* functions, that is, chemicals with more than one functional group. He is well advised to do so because there is no rational way of explaining this principle though Chemical Abstracts and others will specify a preferred order of precedence—acid before aldehyde, aldehyde before ketone, ketone before alcohol, etc. Cahn would agree with this order. I.U.P.A.C. does not stipulate a preferred order. Since most chemicals in the U.S. and Great Britain are named by this order one can conclude, in the example shown, that the principal function is the acid function. It is assumed by now that the reader understands that each chemical name can be parsed quite simply into a series of short letter sequences, i.e. morphemes. By reference to Table XII, it will be noted that each of these morphemes has an associated meaning. The *oic acid* at the end of this name is such a morpheme as are *di* and *en* which precede it. *En* is a bonding morpheme, that is, it denotes *unsaturation* in the basic carbon chain of the molecule. Unsaturation refers to the removal of hydrogen atoms attached to carbon atoms to form double bonds. The entire structure of organic nomenclature is based on the theory of covalent bonds.

Most Unsaturated Straight Chain

In naming this chemical no difficulty would arise concerning the next principal group as

there is no choice here between two sometimes perplexing alternatives of a shorter chain with greater unsaturation and a longer chain with no or less unsaturation. If there were, then the chain with the most double and triple bonds would be selected. This would be the case, e.g. if there were a side chain containing two additional double bonds. As the second priority item in naming a chemical, the saturation is indicated second from the right. In other words, the so-called principal functions come at the end of the name preceded by bonding morphemes when this is possible.

The Longest Chain

The third criterion for selecting the proper name is the principle of the longest chain. By this is meant not the longest chain of atoms, but the longest chain of consecutive carbon atoms. There is, indeed, a school of thought that prefers the principle whereby the longest chain is used, regardless of the atoms involved. A good case can be made for it in many instances. In this particular chemical, the longest chain of carbon and nitrogen atoms is fourteen. The longest carbon chain is eight atoms long and that is why the next morpheme to the left of *dien* is *octa* signifying an eight carbon chain (C–C–C–C–C–C–C–C).

Numbering

After making the decision as to which sequence of atoms in the molecule will become the *parent*, then one numbers each of the contiguous atoms giving the atom to which the functional group is attached the lowest number. In our example, the *oic acid* function is the principal function, consequently the numbering pattern will be $(HO)O{=}\underset{1}{C}{-}\underset{2}{C}{-}\underset{3}{C}{=}\underset{4}{C}{-}\underset{5}{C}{=}\underset{6}{C}{-}\underset{7}{C}{-}\underset{8}{C}$. This will explain the numerals preceding diene as the two double bonds are located between carbon atoms 3 and 4 and atoms 5 and 6.

Substituents or Prefixes

Once the selection of the parent chain has been completed, as well as adding as suffixes, the bonding morphemes and the principal functions, it only remains to name the substituents or side chains, all of which may be regarded as radicals, groups, or sub-names depending upon the complexity of the chemical. In this particular case there are three hydroxy groups at the third, fourth, and eighth atoms. They are specified by using the numerals 3,4,8 followed by the numerical prefix *tri* followed in turn by the morpheme *hydroxy,* hence *trihydroxy.* The remaining substituents in this name are themselves substituted as e.g. *butylamino* which means that there is a *nitrogen* atom attached to the seventh atom in the *octane* parent structure. Ordinarily, amino implies the replacement of one hydrogen atom by the amino group (NH_2), but in this case, one of the amino hydrogens is also replaced by a radical, the *butyl* radical, which is composed of a four carbon chain. Hence, *butylamino* is $CH_3CH_2CH_2CH_2NH-$. By a similar building up process, the last portion of

this name, *(diethylaminopropyl) amino* is the following: $(C_2H_5)_2$–N–CH_2–CH_2–CH_2–N–. However, since the parenthesized expression is preceded by *bis*, it simply means that the other bond on the right most nitrogen has the same chain repeated, which means we really have, for this side chain $[(C_2H_5)_2$–N–CH_2–CH_2–CH_2–$]_2$N–, i.e. *bis(diethylaminopropyl) amino*. The 3- preceding diethyl simply specifies that the left most amino group is attached to the third carbon atom in the *propyl* chain.

This sketch of the rules and explanation of this very complex example does not cover all of the problems. Of interest to the linguist is the choice of allomorph to be made e.g. for *OH*, the hydroxy group rather than *ol*. It is only when the principal function is an alcohol that this latter morpheme is used. Were the carboxyl group (oic acid) to be replaced by another hydroxy group, the name of this chemical would change considerably, but primarily by the elimination of the prefix *3,4,8-trihydroxy* and the addition of *tetrol* as a suffix giving us a name ending in *octa-3,5-dien-1, 4,5,8-tetrol*.

Since chemicals can be prepared with a multitude of different permutations and combinations, the reader can well imagine the difficulties one may encounter when having to make a preferred choice. It is no small wonder that chemists arrive at different names. If considerations of cyclic nomenclature are introduced, then the absurdities of nomenclatural logic increase to the point where there is mass confusion. If the principal function is attached to a ring, i.e. cyclic, then it is the cyclic system which is given priority over the acyclic chain, no matter how long, but if the principal functional group is attached to a chain and that in turn to a ring, the British would treat the cyclic radical as a substituent, while the C.A. indexer would take into consideration the complexity of the cyclic substituent and more than likely call it the principal function.

In closing this discussion, it is worth emphasizing that in spite of the variations in naming chemicals, one generally will have no difficulty in figuring out the chemical involved, because it can always be pieced together by reference to the dictionary of morphemes. If that were not the case communication between chemists would have ceased long ago. This is not to underestimate the difficulties of decipherment. In general such difficulties arise from the fact that the distraught chemist trying to use "systematic" nomenclature, invariably forgets one of the rules and in his confused state generates an ambiguous name. He does not always take the trouble to ask another chemist to try deciphering the name he has chosen. Wiser chemists rely strictly on structural diagrams. Perhaps this accounts for the success of the Japanese chemists who are used to working with ideographs. In this connection, a closing quotation from the British Chemical Society's heated disucssion of the Geneva Conference in which it is said "Prof. P.F. Frankland thought names unnecessary, and that it would be better for the purposes of a register to use formulae." (Armstrong, H.E., opus cited p. 130) seems both pertinent and ironically, prophetic.

Table XII can also be used as a condensed review of I.U.P.A.C. nomenclature. It covers twenty-three primary generic groups of chemicals synthesized by the organic chemist. Each type

is shown by indicating an *R* group, the conventional symbol for *radical* attached to the appropriate functional group. Following the generic name, the most commonly used morpheme is listed. For any specified value of R and/or R′ one can quickly determine the sort of chemical name to expect. In this experiment, particular attention was given to compounds where the R values would consist of the homologous series *meth, eth, prop, but, pent, hex, hept,* and *oct,* i.e. where R equals one, two, three, etc. carbon atoms. Finally, the calculational value for each morpheme is shown. This can be used in applying the algorithm for the calculation of molecular formulas. A more complete list of the morphemes used in the experiment is shown in Table VI on pages 30–31.

TABLE XII. SUMMARY OF I.U.P.A.C. NOMENCLATURE

Structure	Generic Name	Morpheme	Value
$R{-}CH_3$	alkanes	ane	DB_0
$R{=}CH_2$	alkenes	ene	DB_1
$R{\equiv}CH$	alkynes	yne	DB_2
R–OH	alcohols	ol	O_1
R–SH	mercaptans	thiol	S_1
R–	radicals	yl	(+)
R–O–R′	ethers	oxy	O_1
R–S–R′	sulfides	thio	S_1
R–SO–R′	sulfoxides	sulfinyl	S_1+O_1
$R{-}SO_2{-}R'$	sulfones	sulfonyl	S_1+O_2
R–CH=O	aldehydes	al	O_1+DB_1
R–CH=S	thioaldehydes	thial	S_1+DB_1
R–C(R′)=O	ketones	one	O_1+DB_1
R–C(R′)=S	thioketones	thione	S_1+DB_1
R–COOH	carboxylic acids	oic acid	O_2+DB_1
RCSOH	thio acids	thioic acid	$S_1+O_1+DB_1$
RCOOR′	salts & esters	oate	O_2+DB_1
R–COX	acid halides	oyl halide	$O_1+DB_1+X_1$
$RCONH_2$	amides	amide	$O_1+DB_1+N_1$
R–CN	nitriles	nitrile	DB_2+N_1
$R{-}NO_2$	nitro derivatives	nitro	$O_2+DB_1+N_1$
R–NO	nitroso	nitroso	$O_1+DB_1+N_1$
$RONO_2$	nitrates	nitrate	$O_3+DB_1+N_1$

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AUTHOR INDEX

SUBJECT INDEX

SUBJECT INDEX (continued)

SUBJECT INDEX (continued)

Innovator of the Bibliographic Control

Laudation delivered by Cristóbal Urbano, Lecturer at the Faculty of Library and Information Science, during the ceremony in which Eugene Garfield was awarded the University of Barcelona's

Honorary Degree the *Doctor honoris causa*,

on 14 June 2016 in the Paranymph Hall of this university's Historic Building.

https://bid.ub.edu/en/37/urbano.htm

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Eugene Garfield

Innovator of the Bibliographic Control and Entrepreneur with a cause

Author:

Cristóbal Urbano Salido
Faculty of Library and Information Science
University of Barcelona
urbano@ub.edu

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Keywords: Scientific evaluation, Citation indexes, Bibliographic control, Citation analysis, Biographies, Garfield, Eugene

Introduction

In summing up the merits that justify inviting Eugene Garfield to become a member of our University's Council of Doctors, I would like to start by asking you to think back to the literature searches you have carried out in recent months to write your research projects or guide your students' work. Think, too, about your actions in relation to the ever complex, delicate operation of gathering evidence for assessing your own research activity, about evaluating competitive research projects or sitting on selection committees for new teaching and research staff.
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Well, many of the information resources and assessment processes that might have sprung to mind are the link between this Council and Eugene Garfield: every day, lecturers, students and researchers use tools for organizing scientific literature that have been developed with Garfield's ideas, projects or products. For a university institution such as ours, which aspires to be a leader in research, the merits that are the reason for this *laudatio* can be considered in terms of disciplines particularly information sciences and documentation, sociology and the history of science and instruments, including a wide range of operations to support and manage research, which affect all members of the university community, regardless of their field.

Our guest today is important because of his achievements in these two areas. For that reason and in its first honorary degree nomination, the Faculty of Library and Information Science did not hesitate to propose an individual whose work affects the scientific activity of all other schools and faculties at the University of Barcelona, whether directly or indirectly, as well as the management of science policy in the Rector's Office.

A new paradigm of specialized bibliographical control

In fact, the tasks of searching for and retrieving scientific information that we carry out on a regular basis are often supported by products developed through the geniality of Garfield, known as *Gene* to his friends and colleagues, so seemingly predestined by his name to his career. Garfield was the forerunner of indexing systems for scientific literature based on citations, so also based on the functional, intellectual and symbolic networks that authors establish between each other when they write their papers and cite the studies that they have drawn on in their research. He created *Current Contents*, the *Citation Index (Science, Social Science and Arts & Humanities)* and the *Journal Citation Reports*, which assign impact factors to scientific journals. However, the importance of his work lies in his conviction that citation is key to representing the content of publications, determining the relationships between studies, and assessing scientific output.

Garfield's ideas and, above all, his perseverance, are what led to the consolidation of citation indexes, which have influenced the search engines that we use every day. Search engines rank web pages by relevance on the basis of links; a tool that bears certain similarities to citations. We can also see Garfield's intellectual ties to the internet if we look back in time. In his early works, which discussed the need to mechanize bibliographic control and indicated that citation networks could provide opportunities to filter information, Garfield frequently referred to H. G. Wells' World Brain (1938), and Vanevar Bush's concept of Memex (1945) in other words, to two authors who we often consider as the intellectual forerunners of the World Wide Web. In 1964, just after publishing the first edi tion of the *Science Citation Index (SCI)*, Garfield wrote a short paper entitled "Towards the World Brain", in which he described his appearance before a US congressional committee dedicated to studying the creation of a national centre for processing research data. Clearly, Garfield did not consider the *SCI* to be just another indexing and abstracting service, but rather part of a radically new approach to information management, which we have experienced in our time with the internet. In his own words, this is what he had to say:

The idea of a World Brain is a general concept towards which we seem to be moving. As things stand at present, the situation in scientific information is quite chaotic. To dramatize this point, there follows below a passage from my testimony before a Congressional committee which has been investigat- ing the need for an American-based World Brain. This testimony may provide a little more insight into the rationale of the Science Citation Index and how it will be a giant step in the direction of the World Brain which, I believe, far from being authoritarian, is a step in the direction of freedom because of the improved communication and access to world knowledge. (Garfield, 1964: 8-9)

Beyond his contribution to the creation of tools for searching the scientific literature, Eugene Garfield is an essential figure for understanding the development of scientometrics, which analyses science through the metric study of research inputs and outputs, and focuses in particular on the analysis of scientific publications.
These reasons, which we will look at in greater depth, explain why Garfield is one of the most widely recognized professionals and academics in the field of information and scientific documentation. I would now like to describe his career in greater detail.

From Chemistry to Information Science

Eugene Garfield was born in New York on 16 September 1925. He graduated in Chemistry from Columbia University in 1949 and became interested in the management of scientific information right at the start of his professional career, when he came into contact with *Chemical Abstracts*, the well-known international index of chemistry literature that has been published since 1907. This interest led him to work on various projects using computer science to solve problems caused by the growth in scientific information, a phenomenon that was already beginning to limit researchers' ability to keep abreast of the developments in their fields.

In 1951, his interest in creating tools to facilitate the search for and retrieval of scientific information led Garfield to work on the Welch Medical Library Indexing Project, undertaken at the Johns Hopkins University and funded by the Army Medical Library, which would later become the National Library of Medicine. The aim of the project was to automate the tasks of indexing medical literature, using punched cards and the "IBM 101 electronic statistical machine". The experience he gained in this project helped Garfield develop two of his key ideas for improving access to scientific information: indexes of contents to help researchers keep up with journals in their field of knowledge, and citation indexes as a way to organize, access and assess scientific literature.

In 1952, Garfield began to use photocopies of the contents of library and information science journals to develop *Contents in Advance*. This tool enabled professionals to consult references to papers even before they reached the shelves, and would eventually become the well-known *Current Contents* service.

In 1954 and as a result of his interest in the management of scientific information, Garfield obtained a master's degree in library science from the School of Library Service at Columbia University. Just one year later, he published a seminal paper in *Science* entitled "Citation indexes for science: a new dimension in documentation

through association of ideas" (Garfield, 1955). This work was based on a term paper in which he explained the bases of citation indexing, from a perspective that can be linked in part to studies on academic social networks in today's collaborative web.

From innovation to entrepreneurship

Garfield has always combined an entrepreneurial spirit with an innovative vision of information retrieval tools. His entrepreneurship led him to market his contents service, *Current Contents*, and to found the Eugene Garfield Associates-Information Engineers consultancy, whose name was changed shortly afterwards to the Institute for Scientific Information. The consultancy carried out documentation projects for various chemical and pharmaceutical companies and this professional contact with chemical information and documentation inspired him to explore the common ground between automatic indexing, automatic translation and the automated processing of chemical formulas.

This explains why he went on to gain a doctoral degree in 1961 from the Department of Structural Linguistics at the University of Pennsylvania, with a thesis on an algorithm for translating chemical names to molecular formulae. He had already begun to explore this area in 1960, when he indexed chemical compounds in the *Index Chemicus*, which is still used on the *Web of Science* portal. It is surprising to us that Garfield's small company generated the doctoral research that he carried out, in contrast to the usual path of spin-offs and start-ups originating from the work of young researchers at a university.

From citation indexes to the bibliometric study of science

In addition to the commercial development of *Current Contents* and the *Index Chemicus*, from 1955 Garfield continued to work on his major contribution to science: citation indexes. The inspiration for this system for indexing scientific literature came from *Shepard's Citations*, an index created at the end of the nineteenth century that continues to be used by law professionals to search for US federal and state rulings through case citations. Garfield immediately saw the methodological potential of *Shepard's Citations* to index the increasing volume of scientific literature. Encouraged by Joshua Lederberg, winner of the Nobel Prize in Medicine in 1958, he put his ideas into practice with the creation of a citation index for the field of genetics, an initiative that resulted in the publication, in 1963, of the *Science Citation Index*, covering 613 journals and 1.4 million citations. Interestingly, the pilot test project funded by the National Science Foundation and the National Institutes of Health that led to this first edition was focused on an index of genetics. However, it was immediately clear that the best service the index could offer geneticists was multidisciplinary, covering all areas of knowledge in the experimental and biomedical sciences.

In short, the competitive advantage of citation indexes over other indexing and abstracts services was demonstrated by their capacity to surpass disciplinary barriers and to facilitate the identification of valuable information in places this would not generally have been sought. Later on, this principle was extended with the *Social Science Citation Index* and the *Arts & Humanities Citation Index*, which can be consulted on the *Web of Science* along with the *SCI*, an even more integrated, multidisciplinary search solution.

The idea of indexing scientific literature through the references it contains was not new. It had been used many years before in small-scale *ad hoc* projects. Looking back, the idea is very simple, but Garfield had to demonstrate his proposal's viability and efficacy with a real, working product: he had to create a mechanical, flexible, multidisciplinary solution for describing the content of scientific literature. Citation indexing meant that it was the researchers themselves who organized scientific literature, through the papers referenced in their studies and uncovering their consumption of information. As we have said, Garfield brought to fruition an idea that was not new but was initially greeted with skepticism by librarians and researchers because of its major technical challenges and the lack of financially solvent demand.

Garfield's contribution is singular because it systematically articulated a concept that already existed in some form (citation indexing) in a new context (of exponential growth in scientific literature) in a large-scale pilot study made possible by the new technology: the beginnings of computer science at the end of the 1950s and start of the 1960s. In this way, he overcame the problem of how to index documents on highly dynamic research areas rapidly and accurately. Because these were novel, rapidly changing areas, they were not fully incorporated into the scientific terminology, and even less into the classifications, thesauruses and other tools used in classic indexing and abstracting services.

After the creation of the *Science Citation Index*, Garfield saw connections between this tool for retrieving bibliographic information and the history and sociology of science, which he became interested in after reading John Desmond Bernal's book *The Social Function of Science*. Citations are the tracks that researchers leave in the course of their scientific activity, which enable them to acknowledge their predecessors, settle intellectual debts and guide readers towards new works in which they can gain greater knowledge. The study of these tracks helps the sociologist and historian of science to observe how disciplines evolve and follow the exchanges between researchers from different schools and traditions.

Garfield and his team kept in close contact with Bernal, Robert K. Merton and Derek de Solla Price, who confirmed how effectively the *SCI* could map relationships from citations, co-citation and the overlap in the literature. This technique can be used to represent the historical development of knowledge and research fronts. As well as providing a tool for searching the literature, citation indexes offered sociologists and historians a new way of exploring the structure of science. So perhaps the most important legacy of Eugene Garfield was to sow the seed of scientometrics as a discipline that has evolved over the last four decades and is now fully consolidated.

Citation analysis and research evaluation

Finally, we should consider Garfield's influence on science management. Clearly, citation analysis is now a standard approach to the tasks of assessing science but Eugene Garfield was also the first to criticize the often unfair, erroneous use of this approach. In many cases this is due to the inappropriate application of the Impact Factor (Garfield, 2006), a bibliometric indicator for evaluating journals that was developed by Garfield and is provided in the well-known selective lists of the *Journal Citation Reports (JCR).* The "impactolatry" (Camí, 1997) that currently taints

assessment processes here has been criticized by Garfield himself. Indeed, Garfield's reflections about uncritical use of metrics connects with the present movement that recently led to the Leiden Manifesto (Hicks et al, 2015), in which leading bibliometrics experts call for research assessment based on a philosophy that we could call "slow" and that should steer clear of simplifications and mechanical applications, particularly when it is people and projects that are being assessed.

However, the excesses of indiscriminate, automated use of bibliometric indicators are not due to the existence of bibliographic databases containing citation data, but to a culture of rankings. This culture, combined with insufficient financial resources to assess people and projects effectively, has led to the prevalence of assessment based on the impact of the journals in which the research results are published, rather than on the intrinsic value of each study or its metric indicators.

In any case (and as in all human activities, regardless of the existence of good and bad practices), Garfield's theoretical and practical studies in the area of information and documentation are essential to understand changes in the behavior of researchers and how their work is assessed. Without the information products developed by the ISI, or those that competitors have designed in recent years, we would not understand the assessment of science policies at an international, national or institutional level. Garfield's contribution to the management of science and technology can be considered key to understanding how science policy decisions are taken today, both when the decisions are balanced and when they are made without proper consideration.

Action from reflection: his writings, a witness of great value

The publishing products promoted and led by Garfield play a key role in his work. The marketing of these tools is a good example of the knowledge transfer that can take place between universities and companies; in this case the Institute of Scientific Information (ISI) of which Garfield has been honorary president since its acquisition by Thomson Reuters in 1992. However, as we have seen, his achievements go beyond providing a good example of knowledge transfer and a constant commitment to corporate research and development. Aside from his role for many years as CEO of the ISI, Garfield has produced a considerable body of literature on the research and reflection he carried out to support the creation of his scientific information products. His studies are described in hundreds of scientific papers in leading journals, both in the field of scientific information and documentation, and in highly prestigious multidisciplinary publications, such as *Science*. However, the nature of his work goes beyond the boundaries of typical research papers in scientific journals. His thoughts on our discipline are described in various works that actually constitute methodological studies, or commentaries on topical issues, such as the bibliometric bases of the Nobel Prize awards.

Particularly notable is the editorial column that Garfield and some of his collaborators published weekly between 1962 and 1993 in the print editions of *Current Contents*. These columns have been gathered in 15 volumes of his work, under the title *Essays of an Information Scientist*. Looking in perspective at this wealth of reflections on the evolution and assessment of science, accumulated week after week, we can state that

Gene was a blogger "avant la lettre", as his weekly editorials anticipated this format of scientific communication, which is so important today in the context of academic social networks on the internet.

We have stated that bibliometric indicators on their own, out of context, cannot be the only reference used to establish the merit of a researcher. However, to conclude this *laudatio* on the singularity of Garfield's contributions, another way of recognizing his achievements is to consider the bibliometric data available in his ResearcherID profile,[1] which is fed by *Web of Science* citation indexes.

Constituting a kind of bibliometric "selfie", these data are exceptional for a man who defines himself firstly as an information and documentation professional; an "information engineer". And they are also surprising for someone whose career focuses more on business than academia, as we have seen. They are beyond the reach of most authors on information science, but also outstanding compared with many researchers in social sciences or information technology, at the intersection of which we can situate his 1,538 published papers, 1,534 of which are cited; the 9,077 citations of his works, and the list goes on. These figures can be summarized in an h-index of 155 (155 of his papers have received at least 155 citations each in the databases that he created).

A list of Garfield's complete works, with open access to the original documents in most cases, along with interviews and personal documents, is available on a website hosted on the server of the Library of the University of Pennsylvania,[2] a centre at which he has lectured in computer and information sciences since 1974. I recommend that the young people who are with us today read some of the older texts, for example, the early years of his *Current Contents* columns and his intense correspondence on the creation of *SCI*. In these texts, we can find the theoretical bases for citation indexing, considered in computer terms, even though the limited capacity of calculation and digitization of information at the time did not lend itself to this approach. To learn more about Eugene Garfield and his work, we could refer to the book dedicated to him in 2000: *The Web of Knowledge: a festschrift in honor of Eugene Garfield* (Cronin; Atkins, 2000).

Garfield, scientist and practicioner with a cause

Eugene Garfield is a leading "information scientist" who has mainly pursued this career outside of academia. He is a producer of databases which have revolutionized the retrieval of scientific information, and with which he has made considerable advances in the fields of the history and sociology of science. For these reasons, and for his example as an entrepreneur, the Board of the Faculty of Library and Information Science nominated Garfield for an honorary doctorate, an investiture that we have the pleasure and honour of celebrating today.

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Notes:

[1] http://www.researcherid.com/rid/A-1009-2008. Dades del 28 de març de 2016.

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Web of Science

The Web of Science (WoS; previously known as Web of Knowledge) is a paid-access platform that provides (typically via the internet) access to multiple databases that provide reference and citation data from academic journals, conference proceedings, and other documents in various academic disciplines. It was originally produced by the Institute for Scientific Information. It is currently owned by Clarivate (previously the Intellectual Property and Science business of Thomson Reuters).

A citation index is built on the fact that citations in science serve as linkages between similar research items, and lead to matching or related scientific literature, such as journal articles, conference proceedings, abstracts, etc. In addition, literature that shows the greatest impact in a particular field, or more than one discipline, can be easily located through a citation index. For example, a paper's influence can be determined by linking to all the papers that have cited it. In this way, current trends, patterns, and emerging fields of research can be assessed. Eugene Garfield, the "father of citation indexing of academic literature," who launched the Science Citation Index, which in turn led to the Web of Science, wrote:

Citations are the formal, explicit linkages between papers that have particular points in common. A citation index is built around these linkages. It lists publications that have been cited and identifies the sources of the citations. Anyone conducting a literature search can find from one to dozens of additional papers on a subject just by knowing one that has been cited. And every paper that is found provides a list of new citations with which to continue the search. The simplicity of citation indexing is one of its main strengths.

The Web of Science Core Collection consists of six online indexing databases:

Containing more than 195 million records

01] Science Citation Index Expanded (SCIE) -previously entitled Science Citation Index- covers more than 9,200 journals across 178 scientific disciplines. Coverage is from 1900 to present day, with over 53 million records.

02] Social Sciences Citation Index (SSCI) covers more than 3,400 journals in the social sciences. Coverage is from 1900 to present, with over 9.3 million records.

03] Arts & Humanities Citation Index (AHCI) covers more than 1,800 journals in the arts and humanities. Coverage is from 1975 to present, with over 4.9 million records.

04] Emerging Sources Citation Index (ESCI) covers more than 7,800 journals in all disciplines. Coverage is from 2005 to present, with over 3 million records

05] Book Citation Index (BCI) covers more than 116,000 editorially selected books. Coverage is from 2005 to present, with over 53.2 million records

06] Conference Proceedings Citation Index (CPCI) covers more than 205,000 conference proceedings. Coverage is from 1990 to present, with over 70.1 million records

Some useful and important web links

[A] https://clarivate.libguides.com/directlinks

Point users to the right database resource within the Web of Science platform using our list of direct links. Link to a database, or even an individual index within the Core Collection. Descriptions are included to help you quickly communicate the resource.

Just copy and paste. Add to your library home page, Libguide curriculum page or anywhere you direct people to tools and resources. Take them directly where you want them to go.

[B] https://wosjournal.com/

The Web of Science Core Collection includes the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (AHCI), and Emerging Sources Citation Index (ESCI).

This website will help researchers to get Web of Science journals list in one click. The site is covering all the subjects. Moreover, the researchers can also check the details of Web of Science journals by entering the journal title into the search box located at the top right corner.

[C] https://www.dypcoeakurdi.ac.in/images/RND/2019uploads/webofscience.pdf

Containing the List of Indian journals indexed in Web of Science and this list is a part of Group A of UGC-CARE List.

[D] https://wos-journal.com/

WEB OF SCIENCE AND ACADEMIC RESEARCHER is an international journal intended to fill the present need for the dissemination of new information, ideas and methods, to both practitioners and academicians in the Law area, Political Science, Philosophy, Psychology and Linguistics. WOS-Journal is concerned with all aspects of Law system in terms of their relationships to each other.

Although materials are presented relating to sections with several subject, the emphasis of the WOS-Journal is to tie together the functioning of these elements and to illustrate the effects of their interactions. Articles that reflect the application of new disciplines or analytical methodologies to the issues of chosen scientific sections are of special interest.

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The WoS-Journal publishes papers that apply quantitative or other techniques to methodological concerns relevant to the Law, Political, Science, Philosophy, Psychology and Linguistics community. Features include original research, brief methodological critiques, and papers that explore new directions for studying a broad range of scientific topics.

The WoS-Journal encourages submissions from scientists, scholars in the broad array of scientific disciplines that are concerned with chosen scientific topics and sections. The Journal tries to find new objective areas, to help authors with qualified papers and make our community wider providing innovative researchers and investigations.

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Articles on

Journal Impact Factor

By

Prof Dr Eugene Garfield

Eugene Garfield devised the Journal Impact Factor !

"Garfield came to see the impact factor as a mixed blessing 'like nuclear energy'. Although he felt that citation indexing and the impact factor could be remedies for the limitations of peer review, he was uncomfortable with their misuse as performance indicators."

Here is a LIST of his Articles on JIF

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Item-by-item audits reveal a diversity of editorial material"
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The Scientist

A Monthly Magazine

The Scientist was founded by Eugene Garfield in 1986.

In 1988, Garfield sold *The Scientist*, part of the *Institute for Scientific Information*, to *JPT Publishing*.

In 2009, the magazine had a round of layoffs, and its owner, *Science Navigation Group*, merged *The Scientist* with a website, *Faculty of 1000*, for peer review and evaluation of articles in biology and medical journals. *The Scientist* moved from Philadelphia to New York in 2010.

In October 2011, its closure was announced but then the LabX Media Group announced its intent to purchase and continue publishing it. The Group officially acquired the magazine at the end of October 2011.

The magazine is published monthly and is available in print and digital formats.

The Scientist is a professional magazine intended for life scientists. The Scientist covers recently published research papers, current research, techniques, and other columns and reports of interest to its readers.

Overview

The main purpose of the magazine is to provide print and online coverage of the latest developments in life sciences research, technology, careers, and business. Subject matter covered by the magazine includes ground-breaking research, industry innovations, careers, financial topics, the economics of science, scientific ethics, profiles of scientists, lab tools, scientific publishing, techniques, product spotlight, and guides.

Awards

The Scientist has won the following:

- 2018 ASBPE Awards of Excellence, Top Ten Award, Magazine of the Year.
- 2016 ASBPE Awards of Excellence, Bronze - Web News Section & another in Infographics.
- 2011 Gold and Silver 'Eddie' Award for Best Business-to-Business Science Magazine, Full Issue.
- 2011 Bronze 'Eddie' Award for Best Business-to-Business Single Science Article.
- 2011 Silver 'Eddie' Award for Best Business-to-Business News Coverage.
- 2011 ASBPE Awards of Excellence, Magazine of the Year.
- Gold 'Eddie' Award for Best Business-to-Business Science Website in the years 2009, 2010.
- ASBPE Awards of Excellence Magazine of the year, circulation less than 80,000 in the years 2008, 2009.
- Gold 'Eddie' Award for Best Business-to-Business Single Science Article in the years 2008, 2009, 2010, 2011.
- 2007 Nomination as one of the Top 10 Business-to-Business Magazines
- 2007 Gold for Best Publication Redesign.
- 2007 Silver for Best Individual/Company Profile for Ishani Ganguli's "A Complementary Pathway".
- Gold 'Eddie' Award for Best Business-to-Business Science Magazine in the years 2006, 2007, 2008, 2009, 2010.

Top TEN popular & important Science Magazines

The magazines featured on our top 10 list have been around for a long time and are widely respected by the global scientific community. Whether you are just curious and wanting to learn more about science or whether you are a scientist in the making, these magazines will provide you with expert information, advice and stats that will take your knowledge of science to a whole new level.

Our top 10 most important and popular science magazines have been ranked in no order of importance. Some of the criteria that we used to make the shortlist include their reputation in the global scientific community, number of years they have been around, their social media following, scope and quality of scientific content and global appeal.

National Geographic

The National Geographic TV channel has millions of viewers from around the world who tune in on a daily basis to watch some of the most mesmerizing programs that cover environmental science and the exploration of all that is both old and new.

The popularity of the National Geographic TV channel has certainly helped boost the popularity of the National Geographic magazine and it is one of the reasons why we have it first on our list. The magazine content is not heavy and hence perfect for those just getting into the sciences.

National Geographic concentrates mostly on natural sciences and provides fantastic pictures and information about the world we live in, space, animals and inventions. This magazine is available in both print and digital form and can be read by all ages. The magazine is issued on a monthly basis and has a subscription fee.

If you are looking to get your kids or grand kids interested in science, then a great way to do this is to give them a National Geographic magazine subscription as a gift.

Discover Magazine

If you want to get a little heavier with scientific knowledge and facts, the next step is definitely Discover Magazine. This magazine has been around since the 1980s and focuses on all of the different sciences in order to cover all bases. Different magazine editions are devoted to different scientific topics which range from maths and physics, medicine and health, evolution, life sciences, inventions and space.

Discover Magazine is for all ages and is available in both digital and print form. This magazine in our opinion is most suited for young adults and above as the content is heavy. If you are researching a particular topic or just want to expand your scientific knowledge, you should think about getting a subscription to Discover.

If you are not certain whether to subscribe to Discover, you can check out the Discover website and read some of the free articles that cover physical

sciences, natural sciences and environmental sciences. In-depth and well researched articles are also present on the website but they are released every couple of weeks. You can whet your scientific appetite with these articles and then decide if you want to subscribe to Discover.

Popular Science

Has to be on the list as this is one of the oldest scientific magazines that is still going strong. Popular Science has been around since 1872 and has evolved quite a bit over the last 148 years. This magazine has a bigger male following than a female following and one of the reasons for that is due to the fact that the magazine focuses a lot on Technology, Gadgets, Cars and DIY items.

While these themes are dominant, Popular Science also goes deeper and focuses on important issues such as data hacking, space, gene-based treatment discoveries for incurable diseases and the latest cutting edge research and experiments. The magazine is available in both print and digital form. We recommend it for both our male and female readers as it provides a wealth of information on a variety of topics.

If our female readers think that this magazine might be too male oriented, we suggest you check out the digital version and read a few articles that interest you as you could end up missing out on some great information due to the stereotyping that Popular Science magazine has experienced in recent years.

Scientific American

The name of the magazine lets you know that it focuses on the American market but the Scientific American makes useful reading for anyone who is keen on finding out more about the latest research, inventions, discoveries and experiments in the world of science. This magazine is available in both digital and print form.

We believe that this magazine is suitable for those who are familiar with the sciences and are looking to further their research or study into different fields of science. If you are just starting out, the information and content found here might be a little too heavy. However, the writers do a great job in presenting and breaking down their information and insight to make it easy for the readers to grasp.

If you are wondering whether you should subscribe to the Scientific America, we suggest you check out their online website and spend a little time checking out their blog which is very information. This will give you an idea into what kinds of scientific topics and content you can expect to find in the magazine.

The Smithsonian

It is another Science magazine that has very strong American influences but will capture the attention of anyone who loves science and research. The magazine is built on detailed research on a variety of topics ranging from paintings, literature, history and the sciences.

This magazine is perfect for those individuals who need access to detailed research. If you are a casual reader, you might find this magazine a little too heavy and detailed oriented. However, the 'Most Popular' section in the magazine should be fine for the casual reader and provide them with interesting information that will make them appear super-intelligent at the dinner table.

So if you are looking for a magazine that focuses on the sciences as well as provides detailed research on different topics, The Smithsonian will be perfect for you. You can subscribe online to The Smithsonian.

The Scientist

If you are looking to become a scientist, you should definitely think about subscribing to The Scientist Magazine. If you are already a scientist but have never heard about this magazine, then read on to learn why this should be a must read for you.

Life science professionals will enjoy this magazine that stresses on providing accurate, factual and entertaining scientific content. The topics range from molecular biology, stem cell studies, genetics and a range of life science interests. The team at The Scientist are highly qualified and get readers up to date with the latest research methods, scientific discoveries, latest technology and innovative procedures being adopted around the world.

If you would like to get a glimpse of what The Scientist is all about, do check out the online website as there are numerous article posts made throughout the week. The Scientist Magazine Facebook page also provides interesting information and currently has over 2 million followers.

New Scientist Magazine

This magazine has its roots in the United Kingdom and has been around since 1956. New Scientist promotes itself as the most popular weekly science and tech magazine in the world. The magazine has a growing fan base in multiple parts of the world including the UK, Australia and the United States. The magazine is available in both online and print mode.

Some of the common topics addressed by this magazine include what it is to be human? Life questions and scientific answers, latest scientific discoveries and the latest scientific news in the industry.

Do check out the online version of the New Scientist as multiple articles are posted on a daily basis that keep you up to date on the most important scientific research and breakthroughs across the globe. The New Scientist Magazine has a thriving Facebook page with over 3.6 million fans and a Twitter following of over 3 million.

Cosmos Magazine

It focuses on the Science of Everything and is perfect for those who are just wetting their feet in the vast ocean of the sciences as well as for those hardcore science nerds. The magazine covers a number of different themes ranging from core sciences, health, nature, earth, space, technology and history.

There is something for everyone at Cosmos Magazine as the writers put out light and heavy content to appeal to their growing list of subscribes. Cosmos Magazine has its roots in Australia and has been around since 2005. You can sign up for the free newsletter or go ahead and subscribe to the magazine.

Cosmos Magazine will give online subscribers the opportunity to go into the archives and dig up old issues that will keep them busy for a long time. The Cosmos Magazine Facebook page currently has over 500,000 followers.

Popular Mechanics

This pop-science magazine definitely favours a male audience as it focuses on 'how your world works'. The topics cover a wide range of do-it-yourself topics covering outdoor, technology, electronics and science related topics. The content can be both light and heavy in order to appeal to readers who are not very hands on as well as those who can quickly grasp the DIY model.

The magazine has been around since 1902 and has continued to evolve in order to stay relevant and in demand. The U.S version of the magazine has only 10 editions per year. The magazine is available in both English and Russian. Readers who would like to learn more about the latest gadgets, tools, space and aviation will enjoy this magazine.

Popular Mechanics has won the National Magazine Award in 1986 and 2008. If you would like to know more about Popular Mechanics, check out its website as there are two podcasts that also shed more light on the topics covered by the magazine.

Science News

This magazine was established in 1921 and since then has been providers readers around the world with the latest news on science, medicine and technology. The magazine requires a subscription fee as the tagline makes it clear that trustworthy journalism comes at a price.

This magazine is suitable for all readers as the focus of the magazine is to inspire, inform and educate readers about science. The magazine can be accessed in print and digital form. If you would like to check out some of the science news that has been published in recent weeks, check out the online website. You will find breaking news on topics such as space, physics, earth, life and humans.

The magazine is published by the Society for Science & the Public and an annual subscription to the magazine gets you a 12-month free membership into the Society. The annual subscription to Science News gives you access to 22 issues. There is also a free digital newsletter that gets delivered to your inbox providing you headlines and summaries of the latest scientific news.

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Obituary

Prof Dr Eugene Garfield

Eugene Garfield, Pioneer of Scientific Indexing, "*Grandfather of Google*," Dies at 91

Eugene Garfield, known for his scientific knowledge indexing system, died on 26 Feb. 2017 at the age of 91 at Lankenau Medical Center after complications from a prior fall.

Originally from New York City and more recently a resident of Bryn Mawr, Garfield created the worldwide indexing system in 1955, which allowed scientists to easily find information rather than sifting through pages and pages in a library.

His index system contributed to data analytics by using chart connections between pieces of scientific literature, which later became electronically available.

Garfield founded the Institute for Scientific Information (ISI) in Philadelphia, a science division of Thomson Reuters Corporation, which is now owned by Clarivate Analytics.

The institute provides research and solution platforms to conclude a "comprehensive coverage of the world's most important and influential journals and research results," according to its website.

Garfield also launched several scientific journals, such as *Current Contents* and *Science Citation Index.* He was the founding editor and publisher of a magazine geared toward scientists, aptly named *The Scientist*, which he created in 1984.

Garfield received a Bachelor of Science in chemistry from Columbia University in 1949 as well as a master's in library science in 1954, and later a Ph.D. in structural linguistics from the University of Pennsylvania in 1961.

He created the journal impact factor, which calculates the annual average number of citations in relation to recently published articles. It was used for "quantifying the reach of a particular journal in the scientific community based on citations of its publications," according to *The Scientist.*

"He was an amazing character whose influence on information science, writ large, can't be underestimated," H. Carton Rogers III, vice provost and director of libraries at the University of Pennsylvania, told *The Scientist.*

Garfield also served as a member of Penn Libraries' Board of Overseers.

"Before [ISI's] Web of Science, scientists and researchers had very inefficient methods for finding and tracing other scientific documents," said C. Sean Burns, an assistant professor of information science at the University of Kentucky. His Ph.D. research was partially funded by a scholarship in Garfield's name.

"The citation database was not just an intellectual achievement, but also an engineering achievement," Burns continued to *The Scientist*. "His work enabled information retrieval to scale up. … This created, basically, the entire information science field as we know it today."

Garfield's work also extended to the basic form of research tools that we all use every day: Google.

According to Annual Reviews — of which Garfield served on the board of directors — Google co-founders Larry Page and Sergey Brin credited

Garfield for PageRank, an algorithm that essentially runs the site's search engine. The co-founders duly described him as "the grandfather of Google."

"Everything he did, he was ahead of everybody in so many ways," said Vitek Tracz to *The Scientist*, publisher of *Faculty of 1000* and a former co-owner of *The Scientist.* "He was a genius of a very special type. Not only because he had this incredible imagination and brain, but he had incredible tenacity and courage."

Garfield was also an avid supporter of Project HOME, a local advocacy group that helps families end homelessness and poverty.

Garfield is survived by his wife, Meher, five children, two grandchildren and two great-grandchildren.

"No matter how important he became, he always had time for everybody," Meher told *The Scientist*. "He always thought of his employees as his extended family.

"He never lost touch with his humble beginnings. He never became arrogant with his success," she added. "I do miss him a lot."

Garfield requested no funeral service.

Resource:
https://www.jewishexponent.com/2017/03/15/eugene-garfield-pioneer-scientific-indexing-grandfather-google-dies-91/

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Obituary

A tribute to Eugene Garfield: Information innovator and idealist

ARTICLE INFO

ABSTRACT

No other individual has had a greater influence on the fields of scientometrics, informetrics, and information science generally than Eugene Garfield. Most of his contributions over the decades are found to have had their origins very early in his career. Chemistry and chemical information launched his career and led to his involvement with medical information, computing technology, and the field of documentation. Content page products provided the foundation to his business, and the singular invention of a citation index for science, his most far reaching achievement, led to many spin offs including journal analyses, historical charting, evaluation, and science mapping. His idea for a science newspaper was derived from his early work in current awareness. The paper concludes with discussion of his management style, approach to business and philanthropy, and how they shed light on his complex personality and motivations.

1. Introduction

With the passing of Gene Garfield at the age of 91 years on February 26, 2017, we have lost one of the great pioneers and innovators of the information age. It was my good fortune to have been associated with Gene for 45 years. It was exciting to be involved in the applications of citation indexing, and it continues to be an intellectually rewarding journey. I think this is because the database he created is an incredible window onto the entire scientific landscape

For me Gene was a larger-than-life figure who was a commanding presence in my working life at the Institute for Scientific Information (ISI), the company he founded. He was in turn an information pioneer, innovator, entrepreneur, a demanding boss, outspoken critic, a fighter for what he believed in, a nudge, a workaholic, a mentor, a father figure, good friend, and generous soul. Clearly, this is a complex picture and most people who have worked with him feel many conflicting emotions. But without his dogged and sometimes annoying persistence, it is unlikely that we would have seen the products, services, and ideas that have been for me and scholars the world over the essential nutrients of our intellectual life. Through his contributions many of us have built our careers

When I went to work at ISI in 1972, I did not realize that I would witness the birth of a new field of scholarship we call scientometrics and informetrics. The development of the new field was made possible in large part by Gene's citation index in combination with the rapidly expanding power of computing

We are fortunate to have many excellent accounts of his life in the form of audio and video interviews and historical accounts written by him or by colleagues (Garfield, 1987; Garfield, 1997, 2007; Thackray & Brock, 2000; Wouters, 1999). What I will do here is highlight some his achievements and how they were an expression of his unique personality, ambition, and idealism

2. Chemical indexing products

We now think of Gene mainly in terms of his most successful and visible products, namely *Current Contents* and the *Science Citation Index*. But his early work was in chemistry and chemical indexing. He studied chemical engineering for one semester at the University of Colorado before joining the army, and after the army continued his schooling at Columbia University. In 1949 he graduated with a degree in chemistry but could not find a job as a chemist. With a recommendation from a cousin who was working on his PhD at Columbia, he got a job in the lab of the prominent chemist, Louis P. Hammett

http://dx.doi.org/10.1016/j.joi.2017.04.006
1751-1577/

His interest in chemical information stems from his work in Hammett's lab. Gene learned how to do literature searches in Chemical Abstracts and also created an index for the chemicals in Hammett's store room which had been synthesized in the lab. He had learned typing in a high school summer course and thought at one point that he might be a secretary. It turned out that this skill was very useful in his indexing work. However, due to some mishaps and explosions in Hammett's lab, he was fired. "I think it might be a good idea if you modify your career expectations" Hammett told him diplomatically (Garfield, 2007, 17)

Gene often said that one reason for his success was his ability to talk to anyone. Attending a meeting of the American Chemical Society in New York, he introduced himself to James W. Perry, a chemical engineer, who had given a presentation on chemical information sponsored by the ACS Division of Chemical Literature. Gene asked him "How do you get a job in this racket?", and invited Perry to dinner at his mother's home. Perry offered him a job at MIT, but before that could happen, the project lost funding. At Perry's suggestion, he went to Johns Hopkins in Baltimore but discovered that his job would be with Sanford Larkey at the Welch Medical Library working on chemical nomenclature. It turned out that Larkey was a friend of Perry. Later on, gaining access to his personnel file at the Welch Medical Library, Gene found out that Hammett, whom he had given as a reference, had written a letter to Larkey stating that "Garfield is an extremely hard worker but not a particularly original thinker." Looking back with a smile Gene would later say, "Was he surprised!" (Garfield, 2007, 18)

His work in chemical information continued in 1954, after he had completed a library degree at Columbia. At that time he relocated to Philadelphia and took a job as a consultant at the drug company SmithKline & French where one of his projects was indexing steroids. These were identified by scanning journal articles. Realizing that Chemical Abstracts was seriously out of date, he came up with the idea for a chemical information service that would quickly identify newly synthesized chemical compounds. This became his first chemical product in 1960 which he called Index Chemicus. Like his steroid work, this was based on a scanning of journal articles. Needing a way to identify and index new compounds, he developed a method for converting chemical names into molecular formulas which could be easily indexed. This conversion method became the basis of his PhD from the linguistics department of the University of Pennsylvania which at 10 pages became, somewhat notoriously, the shortest PhD dissertation ever granted by the department

3. Contents page services

In some ways, the foundation of Gene's career was the idea of providing the table of contents pages of journals in a timely manner which served the needs of readers to find out the latest publications in their field and of publishers to publicize their

Fig. 1. Gene Garfield in the 1950 with an early version of Current Contents.

upcoming content. In fact, *Current Contents* was the first, best known, and most commercially successful of his products, and for many years provided a critical source of revenue for his other ventures (Fig. 1).

One event in his early life remarkably foreshadows his later interest in title scanning. As a young boy his apartment in the Bronx was across the street from a branch of the New York Public Library. He recalls going into the adult section of the library and reading the titles of books on the shelves until he could see them in his head. Late in life he could still recall some of the titles. Was this a refuge from adversity, simple curiosity, or bragging rights? He could not say.

His first job in the field of information was, as mentioned, working at the Welch Medical Library at Johns Hopkins in Baltimore. The Welch project was sponsored by the Army Medical Library and was the precursor of the National Library of Medicine where, among other things, pioneering work was done on what would later become Index Medicus, and the Medical Subject Heading (Mesh) system. At the project he got to meet many of the leading librarians of the day. Part of his job was to work on the Current List of Medical Literature, a publication of titles of medical articles indexed by the project. On his own and without the approval from the project's director, Larkey, Gene decided to produce a similar service for library and information science journals which he called "Contents in Advance". To compile it, he wrote to journal publishers to obtain the contents pages of their forthcoming issues which he reproduced photographically. He had realized in his work on the Current List and also with Chemical Abstracts that indexing services were very slow due to the amount of indexing work required to produce them. His solution was to create a product that would alert readers to new articles as soon as they were available from publishers. This emphasis on timeliness became one of his mantras and affected every other product he produced.

Larkey, however, did not approve of Contents in Advance, even if Gene was doing it on his own time, and his refusal to stop work on it led to his being fired from the Welch project. However, the publication continued after he left the project and went to Columbia Library School. Later on, after relocating to Philadelphia, he undertook other specialized contents page products for management and pharmaceutical journals which eventually morphed into the various editions of *Current Contents* (CC).

4. Punch cards and computers

The advent of computers and punch card technology for storing and searching data had opened up new horizons for libraries and information centers. Gene got his first exposure to this technology on the Welch project. There he gained his reputation as an IBM punch card "guru" and information "engineer", as he called himself, and an expert at programming the IBM 101 statistical machine which had newly arrived in a building across the street from the library. This involved programming the IBM 101 by the method of rewiring which he learned from reading manuals and talking to IBM representatives. He was able to program the machine to search simultaneously on multiple classification codes of medical articles through the method of superimposed coding which had been developed by Calvin Mooers. One of Gene's earliest published papers in 1954 dealt with the use of punch card technology (Garfield, 1954).

He had a talent for seeing how what we would now consider to be primitive computer technology could be applied to solve large scale information problems. This was particularly true in his proposal for a citation index for science. In effect, he was able to find an engineering solution to an information problem, using punch card technology to store and manipulate the data records.

After leaving the Welch project and completing his library degree, he wanted to pursue a PhD and tried to put together an interdisciplinary committee since Columbia did not have a PhD program in library science. The title of his proposal was "Machine Methods of Scientific Documentation: the Application of Computers". However, he was thwarted in his efforts when it proved impossible to convene the committee. He initially set up his business in Philadelphia first calling it "DocuMation Inc.", later changing it to "Eugene Garfield Associates – Information Engineers". However, he was informed by the State of Pennsylvania that he could not call himself an engineer because he had not been licensed.

5. Citation index for science – conception

The origin of the idea for a citation index for science holds particular fascination because, of all of Gene's innovations, it has had the greatest impact, not only on information retrieval, but also on the field of scientometrics. In the 1950s the idea of creating a unified index for all of science was gaining momentum, including a possible role for the Federal government in building a national documentation center for science (Garfield & Hayne, 1955). Early ideas included combining of information from all the then available disciplinary services into one giant enterprise. Centralization and government support seemed important not only because of the magnitude of the task but also the need for cross-disciplinary research.

The head of the advisory committee at the Welch project, Chauncey Leake, had been pestering Gene to study review articles and find out why they were so important to scientists. He studied reviews and realized that almost every sentence was like an indexing statement associated with a bibliographic reference, like "a continuous string of indexing statements" (Thackray & Brock, 2000). His first thought was that perhaps these statements could be used somehow in his indexing work on the Welch project and he wrote a paper on the idea (Garfield, 1952, 1963). Thus, Leake's suggestion had focused Gene's attention on references in scientific papers.

The next piece of the puzzle came from an unexpected place, via a letter from William Adair, the retired president of Shepard's, a citation index to legal decisions (Wouters, 1999, 23). Adair's letter had been prompted by a conference held at

Fig. 2. Gene Garfield (second from left) at the Symposium on machine methods in scientific documentation in 1953.

the Welch Library which Gene had played a major role in organizing. The opening speaker was Lowell Reed, a vice president of Johns Hopkins, whose statement that "man was going to drown in a flood of papers" was picked up by the newspaper wire services and came to Adair's attention in Colorado (Fig. 2).

The letter from Adair suggested that the legal citator idea used in Shepard's might be applicable to science, and that indeed he had suggested that it be used to index the medical and engineering literature back in the 1930s. Shepard's enabled lawyers to look up an older court decision and see whether more recent cases had affirmed or overturned the original one. Since Gene had never seen Shepard's, he went over to the Enoch Pratt Central Library in Baltimore to have a look. Putting the citator idea together with his insight into how review articles index references, the lightbulb went off.

While at Columbia for his library degree, he wrote a term paper on citation indexing which became the basis of his landmark 1955 paper in Science (Garfield, 1955). In his new role as an associate editor of American Documentation, he also asked Adair to write a paper on how the citator idea could be applied to scientific literature (Adair, 1955).

Gene's 1955 Science paper described how a citation index could be constructed from elemental building blocks of citing and cited records that could be numerically coded to fit into the 80 columns of an IBM punch card. The index also required an inversion of the order of references from how they are presented in the literature to their arrangement by cited item, so that a user could look up a reference and find where it had been cited, turning the usual order of presentation on its head.

The paper stressed the value of a citation index for information retrieval, especially in bringing to light criticisms of earlier papers, to prevent the propagation of "uncritical citation of fraudulent, incomplete or obsolete data". On a more positive note, he went on to say that a citation represents an association of ideas between citing and cited authors, and that this association is at the "molecular" unit of thought, rather than the more general subject category level of traditional indexes. But, he asserted, the citation index could also be used in historical research to assess the "impact" or "significance" of a work for its historical period, including the transmission of ideas, and would enable historians to "measure the influence of the article – that is its 'impact factor'". In short, he saw the value of citation indexing both in terms of retrieval of highly targeted information and for assessing impact, a dual purpose that set the framework for much of the work to follow.

Fig. 3. From left, Hilary Koprowski, Gene Garfield, and Joshua Lederberg at an ISI Board of Directors meeting.

6. Science Citation Index – birth

Initial efforts to obtain government funding to create a citation index, however, were not successful, in part, because Gene was not affiliated with an academic institution. He also attempted to sell the U.S. Patent Office on the idea of a citation index for patents. The National Science Foundation had also turned down his proposal, but he did get support from Gordon Allen, a geneticist at the NIH. Wouters has described all the twists and turns in getting the citation index off the ground (Wouters, 1999).

Then in 1959 Gene received a letter from Joshua Lederberg who had recently received the Nobel Prize (Lederberg, 2000). He had read Gene's 1955 paper in Science and wrote to him asking what had become of the idea. Lederberg said he could have used such a tool himself to see if there had been any follow up work on a previous paper, the very task that a citation index was designed to do. There ensued an exchange of letters between the two that had a decisive effect on the development of the citation index (Fig. 3).

The sequence of letters shows how Gene's thinking evolved on citation indexing, and some of the paths not taken. The basic idea of a comprehensive unified citation index outlined in the 1955 paper appealed to Lederberg. But Gene worried about how such a broad approach could appeal to more specialized communities such as geneticists or journal publishers. Should there be some kind of selection of references to specific journals or papers based on a scanning of reference lists? Should all references from general journals be captured and then select from these an index just for genetics? Or should the index be based on a broader scanning of references, say from all CC journals, but restricted to general science journals as cited targets? Should the index be sliced up by cited journal and provided separately to publishers?

In addition, Gene wondered if the citing sentences should be classified in some manner, or perhaps a page or reference number given to allow users to find where the citation appeared in the article (Lederberg, 2000, 55–57). Should there be coding of references by function, such as confirmation or refutation, or by type of use made by the citing author, or perhaps an indication of the section of the paper the citation came from? He was toying with the idea that knowing the specific citing passage could be very useful, recalling his Welch project study on using review papers as a means of indexing papers they cite.

Lederberg, for his part, was skeptical of many of these qualified or restricted approaches and urged Gene to stick to the original plan of a unified index and full coverage of a set of journals. He urged him not to pursue some of the more intellectually challenging approaches like coding citations by function, but rather to keep it simple and just capture the citing and cited identifiers with minimal additional coding. Lederberg suggested going to NIH with the full concept and felt that they would see the benefits of being able to see how scientific papers had been followed up on. He also brought up the idea that NIH could use such an index in evaluating its "impact on scientific progress". Later on, Gene could explore the

more in-depth research on the nature of citation. "I feel", he wrote, "a good general CI will be of greater value to Genetics than a too specialized run that sticks too closely to the discipline." (Lederberg, 2000, 63). The submission of proposals both to NIH's genetics study section and NSF were ultimately successful. Due to later changes in rules that prohibited NIH giving grants to companies, the money had to be transferred to NSF and converted to a contract.

It is interesting to speculate on what might have happened if Gene had decided to pursue some of the refinements of citation indexing described in his letters to Lederberg, such as coding reference locations within the text or citation function. Clearly adopting any of these refinements would have vastly increased the production effort and probably endangered the whole project. In the first citation index for 1961 and in all subsequent indexes, there is no indication where within the citing paper the citation occurs, and citing items are only identified by initial page. This simplification made it possible to scale up the index through automation without introducing the need for sophisticated indexing.

More recently, of course, issues around how authors cite have become a major research topic under the general rubric of citation context analysis (Small, 1982), and with the advent of more extensive access to full text in electronic form, Gene's original vision of a combined citation and linguistic analysis looks more and more like an attainable goal. In later writings he seemed aware of the possibility. In a 1999 tribute to the late Fred Kochen, he wrote: "It is already possible to use citation links, that is, references, to go back and forth from indexes to full-text journals." (Garfield, 1999)

In 1959 Lederberg also backed up Gene's idea that citation indexing would be valuable for locating interdisciplinary work. The 1955 paper had stated that "cross-fertilization of subject fields is one of our most important problems in science literature." Lederberg had complained: "I have to spend a fair amount of effort in reading the literature of collateral fields and it is infuriating how often I have been stumped in trying to update a topic, where your scheme would have been just the solution!" (Lederberg, 2000, 39) Lederberg's own field of genetics was, he thought, especially suited to citation indexing due to its multidisciplinary nature, involving contributions from disciplines such as biochemistry, statistics, agriculture and medicine. As it turned out, the Genetics Citation Index was created as a subset of the 1961 multidisciplinary index that covered 613 source journals. In addition to a single year genetics subset, an experimental five year genetics index was created covering 38 journals, as was a fifteen year index covering three journals (Garfield & Sher, 1963).

The creation of these subset indexes for genetics, however, proved to be far from straight forward, involving selecting citation records based on both genetics journals and authors (whether citing or cited), matching against specially compiled lists of genetics researchers and journals. Henceforth, the company decided to stick to the original idea of a unified, multidisciplinary citation index covering a selected set of source journals from all fields of science for a single year. As successive annual indexes were compiled, the citations could cross chronological as well as disciplinary boundaries. Lederberg suggested the product be called the *Science Citation Index* (SCI).

An important technical innovation of the first citation index was the introduction of methods to unify cited references. This effort was led by Irv Sher, ISI's first director of research (Garfield, 2001). It turned out, that authors cited papers in different ways using different journal abbreviations and different spellings of author names. Some method was needed to bring together these variants. Otherwise, it would not be possible to gather source papers together that cited a given paper, one of the main objectives of a citation index. By using cleverly constructed keys involving various elements of the bibliographic reference, they succeeded in unifying most of these variant forms. In later years this would also enable the matching of cited references with source article records as required for constructing historical networks.

Following the completion of the first annual SCI for 1961, Gene attempted to get NSF funding for the printing and distribution of the annual index. When this request was turned down, the company had to make the difficult and risky decision whether to fund this effort themselves. As it turned out, initial sales of the SCI were weak, partly due to its high price, and the product lost money for several years. In 1965 he was advised to seek investors from Wall Street which led to his selling 20 percent of the company for half a million dollars. In retrospect, Gene said, this outside money was not needed and the SCI eventually became profitable. The outstanding shares posed problems in later years when a large publisher attempted to take over the company.

By the mid-'60 s the availability of weekly updates of citation data enabled the creation of another current awareness product, the Automatic Subject and Citation Alert, or ASCA report. This was a weekly printout of articles matching a search profile which was submitted by the user. The system was written by Irv Sher and was able to retrieve articles using complex Boolean combinations, what Gene called a "Chinese menu" of key words, authors, and cited references. Despite Gene's enthusiastic support, this product did not take off the way he had hoped, in part due to the difficulty of getting scientists to submit profiles, and was eventually made obsolete by on-line search systems (Fig. 4).

Citation indexing was a radical departure from the traditional methods of indexing and abstracting employed by discipline-based services like the established chemical and biological services which were based on finding the best nomenclature or indexing terms to describe a scientific article, but ignoring the genealogical aspects of the article captured in the cited references. The citation index was the first pan-scientific database knit together by scientists' own handiwork. Scholars still debate what a citation means, whether it represents "influence", "usage", "tradition", or just window dressing. But it seems clear that Gene was aiming for something higher that spoke to the way science was knit together, and the very social nature of that interdependence. Perhaps in simplest terms it represented for him the transmission of knowledge between scientists, somewhat analogous to the passing of genetic information from parent to offspring.

Fig. 4. Irv Sher, ISI's first director of research.

7. Historiographs

Gene was able to illustrate this knitting together of ideas over time through the concept of the "historiograph", a graphical representation of citation relationships between scientific papers covering several generations. The idea had come from Gordon Allen at NIH who suggested in a letter to Gene in 1960 that network diagrams could be used to show historical citation relationships and provided an example (Wouters, 1999, 53). Gene responded enthusiastically to this suggestion saying that such an application had not occurred to him. In 1964, Gene and Irv Sher published an extensive report on one such network, for the field of genetics, matching it against the historical account given by Isaac Asimov in his book on the history of genetics (Asimov, 1963; Garfield, Sher, & Sher, 1964). Taken in a collective sense, the historiograph defined a community of researchers, a body of literature, and evolving knowledge on a topic. Finding a clear way to present complex networks, however, proved difficult.

It is significant that Gene's last major research project was to develop software to construct and visualize historiographs called HistCite, thereby automating the process that had been so laboriously carried out in 1964. For this purpose, it was also possible to take advantage of the multi-year cumulation of citation data represented by the Web of Science. The HistCite software that he and a group of programmers from Russia under Alexander Pudovkin created has been used by a number of scholars to analyze the history of research fields (Garfield, Pudovkin, & Istomin, 2002).

8. Journal citation analysis

One of the key questions in creating the citation index was what journals should be covered as "source" journals, that is, journals from which all references should be captured. Estimates of the number of journals in science at the time varied widely from 50,000 and up. But how many of these were important to cover? Financial constraints necessitated that the first citation index cover only about 600 journals. Gene and Lederberg agreed that covering the big multi-disciplinary journals like Science and Nature was a priority, but how to select the others? Critics like John Ziman were quick to point out that some key journals had been left out. As the SCI gained traction in the market, journal publishers and editors clamored to get

their journals covered. Gene had the insight that the most important journals would cite other key journals, but to study that required a new kind of analysis.

Early flow charts were drawn up by Irv Sher for the creation of a journal citation index where the article level citation index was summarized on the cited journal as well as the citing journal. Serious experimentation began in the late 1960s. This summarization transformed the article citation network into a journal network where nodes were either cited or citing journals. Initially, a quarterly sample from the 1969 SCI was used. The biggest obstacle to this work was the variation in the way authors cited journals, necessitating a large scale manual unification of cited journal abbreviations.

It quickly became evident that only a couple of hundred journals of the roughly two thousand journals covered at that time accounted for a majority of the references received. This justified in Gene's mind limiting the coverage of the SCI to a relatively small number of core journals compared to the tens of thousands of journals that were alleged to exist. In his 1972 article in Science on journal citation analysis, he claimed "... a good multidisciplinary journal collection need contain no more than a few hundred titles." (Garfield, 1972) He dubbed this the "law of concentration" (in contrast to Bradford's law of scattering), and maintained that no matter what disciplinary or specialized journals were selected as source journals, the same set of highly cited core journals would emerge (Garfield, 1971).

He also noted that the highly cited journals were also the largest in terms of number of published articles. This led him to explore ways to "discount the effect of size", that is, normalize the journal citation counts for journal size, settling on the ratio of citations received by a journal in a two year period divided by the number of published or citable items in that period which he dubbed the impact factor.

The Journal Citation Reports (JCR) was the culmination of this effort when it became an ISI product in printout form and later a book printed along with the SCI. The JCR also introduced a number of journal metrics besides impact factor, such as the immediacy index, and half-life statistics dealing with the time distribution of citations received or given. These data were used to guide journal selection, and were adopted by journal editors and publishers, as well as by some librarians as measures of a journal's performance. However, they remained controversial within the research assessment community, particularly as a surrogate for assessing the performance of individual papers or scientists. Within ISI, the JCR data were extensively used to carry out custom analyses to study journal coverage in various products or to plan coverage for new products such as the Social Sciences Citation Index. Analysis of specific fields could be performed, such as, starting with the core journals in some field, and summarizing their cited and citing journals. Soon the JCR opened up new opportunities for studying the interaction among journals or journal sets which were taken up by scholars in the new field of scientometrics.

9. Evaluation by citations

In Gene's 1955 paper on citation indexing, the evaluative use of citations was noted but not emphasized. For many years he stressed the primacy of the SCI's use for information retrieval, downplaying its secondary use in evaluation. This may in part have stemmed from a concern that sloppy or inappropriate use of SCI data would reflect badly on the product, and he vigorously defended it against such abuses. He also warned against the use of the impact factor in evaluating individuals. In his view, "Using citations for evaluating people is a very tricky business." (Cawkell & Garfield, 2001). Citation counts depended on, among other things, the field of science, time factors, and nationality, and a proper evaluation of an individual, paper or journal needed to take multiple factors into consideration. In later years he worried that the use of the SCI for evaluation had eclipsed its use for retrieval; in effect, "the tail was wagging the dog". (Garfield, 1998)

He also saw the shortcomings of individual scientists' referencing practice, and sometimes chastised individual scientists for their failure to cite relevant papers, as in the case of Watson and Crick's failure to cite Avery for the identification of DNA as the hereditary substance. At the same time he realized that such omissions were part of the complex competitive social relationships of scientists.

His first systematic use of citation counting was made as part of his study of the history of DNA in 1964 where he used the 1961 citation index to count the number of citations to nodal authors in the DNA historiograph (Garfield et al., 1964). This study also includes comparisons of citation rates of Nobel Prize winners to other genetics authors in the historical network, and presages his later interest in using citation counts to predict future prize winners. The highly skewed nature of the citation count distribution also became apparent. Clearly high citation rate and utility were bound up in an important way (Garfield, 1973). What Gene did achieve was to transform the way people looked at research performance, from simply how many papers were published to how often they were cited.

Despite his reservations toward evaluation, he was not hesitant to use SCI data to celebrate and highlight the achievements of scientists. He regularly published lists of highly cited authors and papers from different fields in his CC editorials. In his project to list the 1000 most cited authors, he opted to list the authors alphabetically rather than rank ordered to avoid the impression that some were more important than others (Garfield, 1981). In 1977 he inaugurated his Citation Classics series which featured commentaries by individual authors of highly cited papers. A few thousand of these commentaries appeared over the years and were reprinted in a series of books.

In a revealing interview with his VP for research, Tony Cawkell, Gene explained his interest in recognizing highly cited scientists: "I came from a socio-cultural-economic family background that cultivated a deep sense of justice. . A lot of people are passed over in the formal reward system of science. . SCI and the citation analysis became for me a vehicle to transform an informal system of recognition into an explicit reward system for science." (Cawkell & Garfield, 2001)

10. An encyclopedia for science

In the lobby of the old ISI building at 3501 Market Street was a holographic etching entitled the "World Brain". This work was commissioned from the artist Gabriel Liebermann. The world brain was an idea proposed by H.G. Wells in a 1938 essay that held particular fascination for Gene, and he wrote often about Wells in earlier papers. Wells's world brain was an idea for an encyclopedia that would synthesize the world's scientific knowledge by combining the existing scientific writings by authorities from all fields, in Wells's words "... knitting all the intellectual workers of the world through a common interest and a common medium of expression into a more and more conscious co-operating unity." (Wells, 1938, 33). It seems clear that, in some sense, Gene regarded SCI as a representation of collective scientific knowledge and a step toward the realization of the world brain encyclopedia. Earlier at library school, he had written a term paper about Paul Otlet's ideas on encyclopedism, and he considered Otlet one of the founding fathers of documentation. In 1981 he would be able to put some of these ideas into operation in a product he called the *Atlas of Science*.

While the historiograph captured the chronological evolution of knowledge, the introduction of co-citation in 1973 opened up the possibility of mapping science in temporal slices or cross sections, and by connecting the major specialties and fields of science, also revealed its interdisciplinary nature (Small & Garfield, 1985). He encouraged the development of co-citation clustering and mapping, and advocated for its introduction into ISI products. Initially this took the form of providing indexing headings for on-line products or specialized indexes such as the Index to Scientific Reviews. Later on, he proposed the idea for an *Atlas of Science* which, initially at least, was to be a compendium of maps and what he called mini-reviews – short summary statements about the nature of a specialty written by scientists or science writers. After a couple of editions appeared in printed form, this product morphed into a series of review journals where the co-citation maps served as a guide to what fields should be reviewed.

11. A science newspaper

Gene had a longstanding interest in creating a newspaper of science and his early ideas date back to the 1960s. His ideas were perhaps stimulated by the success of CC in providing up to date information on what was going on in science. Weekly issues of CC already had the feel of a newspaper. Why not expand the idea? (Garfield, 1975) However, just what such a newspaper would provide underwent many transformations. One early idea was to have a Daily Scientist tabloid that, analogous to stock market listings, would update citations to scientists' papers. Since the company was located on Chestnut Street in Philadelphia in 1961, the name Chestnut Street Journal of Science was floated. Other ideas were to publish articles written for a non-specialist audience, to publish abstracts or even rapid publication of original articles. All of these options, however, would involve a substantial outlay of capital for paper, printing and mailing, and therefore the need for outside investments. In the 1970s, the possibilities of electronic distribution were investigated, modeled after television based systems such as Viewdata or Prestel in Britain (Garfield, 1977). Meanwhile, more and more editorial features were added to the CC front matter in addition to his weekly essays that began in 1962 under the heading "The Informatorium". Features such as Press Digest gave CC more the feel of a news magazine.

Eventually, in the mid-'80 s his ideas gelled around doing a magazine that focused on the business and profession of science, with discussions of science funding, politics, and the job market, and in 1986 *The Scientist* was launched (Garfield, 1986). Together with other new products at the time such as the *Atlas of Science*, *The Scientist* put considerable strain on the company's finances and led in 1988 to Gene's divesting a controlling interest in ISI to an outside investment firm, JPT Holdings, an acronym for the first names of the owners, Joe, Paul and Ted. He later claimed that the new management had misled him into thinking that support for *The Scientist* would continue, but like other newly launched products, this proved not to be the case and the magazine project was terminated. The only option was to continue to support the effort on his own, and spin it off to a separate company which he did in partnership with Vitek Tracz.

12. Gene as boss

We had a memorable first meeting. I had written Mort Malin, ISI's vice president for Corporate Development, and asked if they had a job opening and sent some of my bibliometric work. Gene was coming to New York City on business so I met him in Penn Station. He was wearing orange socks. We went for coffee but he had forgotten to bring money and had to go to a Western Union to have some wired from Philadelphia. We hailed a taxi but then he realized he did not know whether his appointment was north or south on Park Avenue, so we had to find a pay phone. Dropping me off, he asked what kind of a guy I was. I said in my mid-western manner that I was just an ordinary guy. He said "at ISI we only hire extraordinary people." I thought, well, I really blew that one. I nevertheless got the job.

Our relationship got off to a rocky start a few months after I joined the company in 1972. I went to his office with a paper I had written on a new type of analysis you could do with his citation index involving jointly cited papers, what I called co-citation (Small, 1973). His initial reaction was that it was presumptuous of me, an unknown and unpublished scholar, to present him with such a fait accompli. At first I thought I would be fired but when this did not happen, I gained more confidence. I realized he respected you more if you stood up for what you believed in. After this initiation by fire, he accepted me as an independent researcher, and I received his enthusiastic support.

Fig. 5. Portion of the Cathedral of Man mural by Guillermo Granizo showing portraits of Merton, Garfield, de Solla Price, and Lederberg.

He saw that I was interested in using the SCI to study the structure of science and gave me a book he considered pertinent, *Numerical Taxonomy*, a treatise on cluster analysis (Sneath & Sokal, 1973). He encouraged me in my work on clustering the SCI using co-citations, and its application to map science. He generally created an atmosphere in the company conducive to experimentation and innovation. Together with Mort Malin, my boss, we worked on a joint paper on science indicators and participated in a meeting in 1974 at the Institute for Advanced Study in the Behavioral Sciences attended by many luminaries in the sociology of science (Garfield, Malin, & Small, 1977). In 1975 I organized a conference on citation analysis inviting many leading sociologists and bibliometricians which was held in a small conference center in Maryland. Gene brought his saxophone and was heard practicing in his room. I think this was a form of relaxation for him. Years later we worked together on other papers, culminating in a joint paper in 1985 on what we called the “geography of science” which was reprinted in the front matter of the SCI for many years (Small & Garfield, 1985). It also led to our experiments in creating an *Atlas of Science*.

The rank and file employees were an interesting group of creative people including quite a few artists, musicians, writers and non-conformists. One reason for this was that many of the jobs in the company, particularly those in data capture, were relatively routine and repetitive but still required a high degree of literacy. But you could forget your job at the end of the day and pursue your real interests. The other reason was that Gene was drawn to such people and enjoyed being with them, and to some extent identified with them. He had an open door policy and anyone could go to see him. He enjoyed these encounters with employees, and his response to their complaints was usually generous and supportive. This intense engagement with staff fostered a sense of loyalty and dedication. Many of his employees stayed many years at the company because of the collegial atmosphere he created. I am very fond of the inscription he wrote in my copy of the first volume of his multivolume *Essays of an Information Scientist*: “It’s a fantastic pleasure to be associated with you in our daily work and in particular as a co-author of these volumes. . Henry, I hope we can get to know each other better in the years to come.”

Not only were artists employed at ISI, Gene decorated his new 3501 Market Street building, a building designed specifically for ISI by a prominent post-modern architectural team, Venturi Scott Brown Associates, with murals and art works, including some that were controversial. The mural called the “Cathedral of Man” by Guillermo Granizo featured cameos of people who were influential in his life like Robert Merton, Derek Price, Joshua Lederberg and information greats, including Gene himself, drawn on orange tiles, his favorite color (Fig. 5).

He was also a lover of the complex and colorful yarn art by the Mexican Huichol artist Emeteria Rios Martinez whose work decorated the walls of the building. In 2009 the company under the control of Thomson Reuters decided to vacate the Market street headquarters that bore the unmistakable stamp of his career and personality, to take up occupancy in a non-descript office building on Spring Garden Street. A part of him and us stayed in the old building (Fig. 6).

When he travelled, which was often, he took issues of CC, ASCA reports and a small red notepad on which he would scribble semi-legible notes to employees on things they should work on. When he returned to the office these notes were sent out. Much time was spent deciphering these missives, and trying to figure out how or if to respond. We all had collections of these notes on our desks, always dreading the follow-up or reminder: “did you reply to Dr. so and so? . . .”, “was this error corrected? . . .”; “did you write a paper refuting this statement? . . .”, “read this and discuss with me”. . . Often he would forget what he had asked you to do, but sometimes these follow-ups would mysteriously reappear to our horror. Even years later, he could suddenly ask you out of the blue “did you ever do that research front animation we talked about?”

The extent of his social network became apparent to me when I occasionally accompanied him on road trips. He seemed to know personally every library director, head of department, and researcher along the way. He was almost a celebrity

Fig. 6. ISI headquarters in the late 1970 at 3501 Market Street, Philadelphia, PA designed by Venturi Scott Brown Associates.

in Europe, more so than in the States. This was brought home to me while on a lecture tour of Europe in 1985. We were walking down a dark street in Zurich when out of the shadows came a figure who said, “Good evening, Dr. Garfield”. He was evidently a scientist who had recognized Gene from his picture in CC. The stranger started talking about incidents in Gene’s life, including when he drove a cab in New York, which he had read about in CC essays. Many people we encountered on that trip felt as if they knew him personally through these editorials.

13. Gene as business man

In the late 1950s the company he formed went through several name changes until finally settling on the Institute for Scientific Information (ISI) in 1960. This name was chosen to project more of an academic and non-profit image, making it easier to sell to libraries and individual scientists. The name was suggested to him by the name of a soviet information organization called VINITI, which translates to Soviet All-Union Institute of Scientific and Technical Information (Garfield, 1987). Perhaps by coincidence, Bernal’s book, *The Social Function of Science*, contained a discussion of a proposed organization called Science Information Institute (SII) which could also have subconsciously influenced his choice (Bernal, 1939, Appendix 8). As a young man he had been given a copy of Bernal’s book by one of his socialist uncles, and Gene considered Bernal one of his intellectual forbearers, endowing an award in his honor at the Society for Social Study of Science (Garfield, 1982) (Fig. 7).

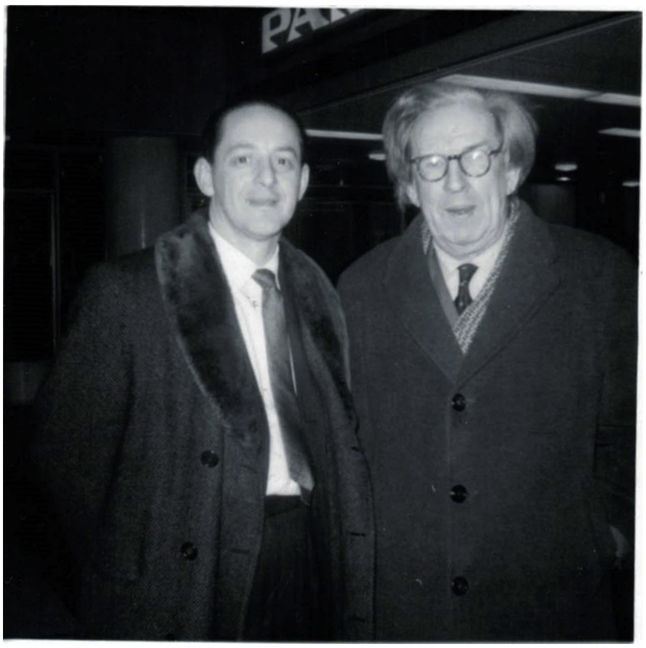

Fig. 7. Gene Garfield and J.D. Bernal in 1958 at the International Conference on Scientific Information, Washington, DC.

Gene considered himself a “super-salesman” and promoter, and the early success of products like CC and the SCI were largely due to his sales efforts. Sometimes his marketing efforts went too far, for example, when he had fortune cookies made up containing the message “the SCI makes you a successful scientist”. The FASEB society would not allow him to distribute the cookies at their meeting.

His approach to products was not that of a conventional business man, but rather as a visionary and innovator. New products often teetered on the edge of profitability. He retained controlling interest in the company and fended off a number of attempts to wrest control from him. If he believed in a product idea and thought it would be useful to customers, there was no dissuading him from pursuing it even if it lost money. Eventually, he thought, customers would see its merits. If someone told him it could not be done, he was even more determined. Some of his early products like the *Index Chemicus* did not turn a profit for many years. In the beginning, he would use the profits from a successful product like CC to fund new products like the SCI which took several years to be profitable.

This approach led to many conflicts within the company. For example, in 1969 a group of four executives – Gene called them the four horsemen of the apocalypse – walked out over his unwillingness to focus on profitability, and formed their own company to compete with ISI. The new company, however, failed and one executive, Irv Sher, rejoined ISI. Gene would later comment how difficult it was to run a for-profit company like a non-profit. He was aware that he had a reputation as a risk taker, or “crapshooter” as he called himself (Garfield, 1987), and admitted that there was an element of ego in his decisions (Cawkell & Garfield, 2001). Eventually, stretched financially, having too many products for which a market had yet to be developed and tired of day to day management, he decided to sell the company (Garfield, 1997).

He travelled often to the Soviet Union to sell products and give talks and he got to know a number of prominent scientists and dissidents like V.V. Nalimov, who had written a book entitled *Naukometria* which translates to scientometrics. Eventually Tibor Braun at the Hungarian Academy of Sciences founded the first journal in the new field using that name. However, some communist countries would only buy one copy of an ISI product, and then photocopy it for distribution. The CC editorials he wrote on topics in American society were interesting to foreigners, but the Soviets were paranoid and heavily censored them.

14. Gene as humanitarian and philanthropist

Gene believed strongly in the positive impact of science on society and the social returns of investing in scientific research, later sponsoring an award for the best paper on the topic at Research! America. He also strongly believed that information products like CC and SCI accelerated the progress of science and ultimately led to economic growth and human welfare. Despite resistance from publishers, he thought open access to the scientific literature would ultimately be realized. He also believed that citations were a form of symbolic reward or currency for scientists which would help them in their careers. As a champion of both private enterprise and social welfare, he was not opposed to government sponsorship of information systems as long as they did not unfairly compete with his own products. He benefited from some government support but was critical of policies that made it more difficult for private companies to obtain that support. His social consciousness is evident in his support of the ACLU.

The child care center he built behind his new headquarters building on Market Street enabled employees to keep their children nearby during working hours, and was perhaps inspired by his experience of being raised by a single mother and also having been a single parent himself. He supported children in other ways, through Project Home in Philadelphia dedicated to alleviating poverty and homelessness, and his sponsorship of Opera Company of Philadelphia rehearsals for school children. He also supported young scholars with doctoral dissertation awards in various library and information schools and societies, as well as a medical scholarship for minority students. When the ISSI society was formed at the 1993 meeting in East Berlin, he agreed to sponsor a doctoral dissertation award.

15. Summation

The reasons for Gene’s enormous influence are many. He began his professional career when computing was in its infancy and information services were almost exclusively provided in printed form. His career spanned the great revolution in computing power culminating in the invention of the internet. The information products he developed were ideally suited to electronic delivery, and their adaptation to the new medium gave ISI tremendous impetus. Equally important was the rapid expansion of science in the post-war era, including a growing government funding for science after Sputnik and the Watson and Crick revolution in biology. His early products were aimed at improving scientists’ access to information. But the most important factor for his success, I believe, was his ability to envision how relatively simple yet powerful ideas on the organization and delivery of bibliographic data could transform the information seeking behavior of users.

He concluded his first letter to Lederberg in 1959 with words that tell us something about Gene’s motivation and idealism: “I have great faith that the citation index will one day be a spur to many new scientific discoveries in the service of mankind.” (Lederberg, 2000, 42)

In 2007 Gene participated in Vitek Tracz’s “Web of Stories” project in which he spoke informally about his life and career on videotape (Garfield, 2007). I was fortunate to be his interlocutor. This turned out to be a marathon session over the course of three days and in these videos you can see his true personality, his joy of life, his incredible memory for names and events, his intellect, and sense of humor.

In talking about how research scientists regard literature searches, he said: "We used to talk about, do scientists really want to do literature searches?. . I said to a librarian, do you think that the average scientist who comes to you is happy when you come up with papers that anticipate his ideas? He's looking to you to prove that it's a novel idea, not that it's unoriginal. . That's one of the dilemmas that we face in using information for discovery purposes. . But people like Josh Lederberg always pointed out that if you're a mature scientist eventually you get over that and his talent, and people like him, is framing questions for which you give them partial answers. . If you're working in the field of genetics if somebody answers some fundamental question, that's what you give people prizes for. But you don't get upset by the fact that somebody like Jim Watson, you know, identified the double helix. You go on from there and you go to the next step, right? So it's your attitude, being mature about it, how you use and await discoveries. There's plenty more to be discovered after your great idea proves to be not so original any more. . That's what make science goes around." (Garfield, 2007, 81)

Gene goes on to discuss his contributions, and that people give him credit for things he did not do. He admitted he was not much of a theoretician and wished he had made more discoveries. He joked that even the so-called Garfield constant is always changing. "You'd like to think that you spent your life doing things that help improve the condition of man. . So I think that the challenges will remain and I hope there will always be interesting and useful questions that people will keep on answering. That there will never be an end to the number of new questions that could be asked. The unanswered questions of science: that was another one of the projects we never finished." (Garfield, 2007, 82)

Ironically, even in his philosophical musing he was reminded of an unfinished project. There is no doubt that the information products he has given us will, as long as they survive, supply us and future generations of scientists with an unending stream of questions and partial answers that lead to more questions, and this is the real legacy of Gene Garfield.

Acknowledgements

I would like to thank Meher Garfield and the Eugene Garfield Foundation for permission to reproduce photographs, and Web of Stories for the use of an interview excerpt.

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Henry Small
SciTech Strategies, Inc., 105 Rolling Road, Bala Cynwyd, PA 19004, USA
E-mail address: hsmall@mapofscience.com

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Derek de Solla Price Memorial Medal

The Derek de Solla Price Memorial Award, or Price Medal, was conceived to honor Derek J. de Solla Price for his contributions to information science and for his crucial role in developing the field of scientometrics. The award was launched by Tibor Braun, founder of the international journal Scientometrics, and is periodically awarded by the journal to scientists with outstanding contributions to the fields of quantitative studies of science. The awarding ceremony is part of the annual ISSI conference. The first medal was awarded to Eugene Garfield in 1984. The full list of winners can be found below.

The awarding ceremony of the Derek de Solla Price Memorial Medal has become an essential part of the programme of ISSI conferences since the foundation of the Society in 1993. The Price Medal was conceived and launched by Tibor Braun, founder and former Editor-in-Chief of the international journal Scientometrics, and is periodically awarded by the journal to scientists with outstanding contributions to the fields of quantitative studies of science. The journal Scientometrics is an international journal for all quantitative aspects of the science of science, communication in science and science policy co-published by Akadémiai Kiadó, Budapest, and Springer, Dordrecht. The first medal was awarded to Eugene Garfield in 1984. The medal was first awarded annually, later, since 1993, biannually.

The procedure consists of two parts: nominating and voting. Nominations are made by a panel comprised of the editors and members of the advisory board of Scientometrics together with former Price awardees. First, the nomination panel is asked to nominate in a non-ranked list up to six scientists they feel have contributed most to the field of quantitative studies of science. Following receipt of nominations, ballots for voting are sent to the committee members. The winner of the award is the person (or team) with the highest score.

List of Awardees

Year	Winner	Year	Winner
1984	Eugene Garfield	1985	Michael J. Moravcsik
1986	Tibor Braun	1987	Vasily V. Nalimov & Henry Small
1988	Francis Narin	1989	Bertram C. Brookes & Jan Vlachy
1993	Andras Schubert	1995	Anthony F.J. Van Raan & Robert K. Merton
1997	John Irvine & Ben Martin & Belver C. Griffith	1999	Wolfgang Glänzel & Henk F. Moed
2001	Ronald Rousseau & Leo Egghe	2003	Loet Leydesdorff
2005	Peter Ingwersen & Howard D. White	2007	Katherine W. McCain
2009	Peter Vinkler & Michel Zitt	2011	Olle Persson
2013	Blaise Cronin	2015	Mike Thelwall

2017	Judit Bar-Ilan	2019	Lutz Bornmann
2021	Ludo Waltman	2023	

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Biography

Derek J. de Solla Price

22 Jan 1922 :<>: 3 Sep 1983

1. Introduction

Derek John de Solla Price (22 January 1922 – 3 September 1983) was a British physicist, historian of science, and information scientist. He was known for his investigation of the Antikythera mechanism, an ancient Greek planetary computer, and for quantitative studies on scientific publications, which led to his being described as the "Herald of scientometrics".

2. Biography

Price was born in Leyton, England, to Philip Price, a tailor, and Fanny de Solla, a singer. He began work in 1938 as an assistant in a physics laboratory at the South West Essex Technical College, before studying Physics and Mathematics at the University of London, where he received a Bachelor of Science in 1942. He obtained a Doctor of Philosophy in experimental physics from the University of London in 1946.

In 1948 Price worked as a teacher of applied mathematics at Raffles College, which was to become part of the National University of Singapore. It was there that he formulated his theory on the exponential growth of science, an idea that occurred to him when he noticed the characteristic logarithmic curve of the *Philosophical Transactions of the Royal Society* between 1665 and 1850, which he had stacked against his wall at home while Raffles College had its library built.

After three years, Price returned to England to work on a second Ph.D., in the history of science, this time at the University of Cambridge. During his Ph.D. studies, he accidentally discovered *The equatorie of the planetis*, a Peterhouse manuscript in Cambridge University Library, written in Middle English, which he attributed to Geoffrey Chaucer. It is now attributed to a St Albans monk called John Westwyk.

Around 1950, Price adopted his mother's Sephardic name, "de Solla", as a middle name. He was a "British Atheist ... from a rather well-known Sephardic Jewish family", and although his *Denmark* wife, Ellen, had been christened as a Lutheran, he did not, according to their son Mark, regard their marriage as "mixed", because they were both atheists.

After obtaining his second doctorate, Price moved to the United States, where he served as a consultant to the Smithsonian Institution, and as a fellow at the Institute for Advanced Study in Princeton, New Jersey. His next post was at Yale University, where he worked until his death, serving as the Avalon Professor of the History of Science, and as chair of a new department that encompassed the histories of science, technology, and medicine.

In 1984, Price received, posthumously, the ASIS Research Award for outstanding contributions in the field of information science.

Since 1984, the Derek de Solla Price Memorial Medal is awarded by the International Society for Scientometrics and Informetrics to scientists with outstanding contributions to the fields of quantitative studies of science.

3. Scientific Contributions

Price's major scientific contributions include:

- **Price's square root law** or **Price's law** pertains to the relationship between the literature on a subject and the number of authors in the subject area, stating that half of the publications come from the square root of all contributors. Thus, if 100 papers are written by 25 authors, five authors will have contributed 50 papers. Price's law is related to Lotka's law and has been likened to the Matthew Principle. It can be modeled using an approximately L-shaped graph, with number of people on the Y-axis, and productivity or resources on the X-axis.
- Studies of the exponential growth of science and the half-life of scientific literature;
- Quantitative studies of the network of citations between scientific papers (Price 1965), including the discovery that both the in- and out-degrees of a citation network have power-law distributions, making this the first published example of a scale-free network;
- Price's model, a mathematical theory of the growth of citation networks, based on what would now be called a preferential attachment process (Price 1976);

- An analysis of the Antikythera mechanism, an *Ancient Greece* analogue computer and astronomical instrument (Price 1959, 1974).

4. Notable Publications

- "An ancient Greek computer", in *Scientific American* **200** (6):60–67 (1959).
- *Science Since Babylon* see review
- "Mechanical Waterclocks of the 14th Century in Fez, Morocco", in *Proceedings of the Tenth International Congress of the History of Science* (Ithaca, N.Y, 1962), Paris: Hermann, pp. 599–602 (1962)
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- Chaucer's astronomy (Weekly evening meeting), 1952.
- Contra-Copernicus, 1952, Royal Institution of Great Britain, ASIN- B0007KCWS6.
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Interviews

of

Prof Dr Eugene Garfield

Here is a LIST of Interviews by him on various occasions/topics.

These could be reached by clicking the respective web links provided herein.

❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖ ❖

Interviews:

1. Family History 4 minutes 14 seconds
2. My family and my relationship with my father 6 minutes 7 seconds
3. Childhood memories 5 minutes 26 seconds
4. Moving to the West Bronx and my stepfather 5 minutes 50 seconds
5. Growing up across the street from the New York Public Library 2 minutes 12 seconds
6. High School 5 minutes 26 seconds
7. My mother 5 minutes 41 seconds
8. My uncle Sam 5 minutes 27 seconds
9. Learning to play the clarinet and the piano 7 minutes 8 seconds
10. Working before University 3 minutes 6 seconds
11. Learning to type and clerking in the army 2 minutes 58 seconds
12. Getting drafted 3 minutes 43 seconds
13. Army training and getting an ulcer 4 minutes 9 seconds
14. Columbia and Berkeley 2 minutes 22 seconds
15. My first wife leaves me and coping as a single parent 7 minutes 18 seconds
16. The origins of Eugene Garfield Associates 8 minutes 5 seconds
17. Jobs after graduation and working for Louis P. Hammett 6 minutes 51 seconds
18. Going to an American Chemical Society meeting and getting a new job 8 minutes 3 seconds
19. Working at the Welch Medical Library (Part 1) 5 minutes 2 seconds
20. Working at the Welch Medical Library (Part 2) 3 minutes 52 seconds
21 Starting 'Contents in Advance' and getting sacked 2 minutes 17 seconds
22. "As a documentalist you make a great career" 4 minutes 31 seconds
23. Writing papers and going to Columbia library school 4 minutes 29 seconds
24. Getting a job with Smith, Kline & French 3 minutes 16 seconds
25. Discovering Shepard's Citations 6 minutes 24 seconds
26. Getting my paper published in "Science" 2 minutes 1 second

27. Looking after my son Stefan and getting married 3 minutes 54 seconds
28. Early days of "Current Contents" 6 minutes 35 seconds
29. The genesis of "Current Contents" 6 minutes 3 seconds
30. 'Index Chemicus' and completing my doctorate degree 7 minutes, 5 seconds.
31. Handing in my dissertation 5 minutes 55 seconds
32. A proposal for the 'Genetic Citation Index' 3 minutes
33. The indexing project 4 minutes 3 seconds
34. Financial problems for the 'Scientific Citation Index' 6 minutes 3 seconds
35. Problems starting 'The Scientist' 6 minutes 33 seconds
36. The ups and downs of the buisness and the office atmosphere 1 minute 16 seconds
37. The impact of scientific information systems on scientific progress 5 minutes 2 seconds
38. Impact factors 5 minutes 33 seconds
39. Historiographs 4 minutes 28 seconds
40. Usefulness of citations for historians 3 minutes 45 seconds
41. JD Bernal, politics, and science 2 minutes 28 seconds
42. Scientometrics, JD Bernal and Joshua Lederberg 6 minutes 15 seconds
43. Moving to Philadelphia to work for Smith, Kline & French 6 minutes 56 seconds
44. People at Smith, Kline & French and paying back taxes 4 minutes 34 seconds
45. My son Stefan 7 minutes 5 seconds
46. My son Josh 7 minutes 50 seconds
47. Job security and outsourcing 5 minutes 7 seconds
48. Irving H Sher (Part 1) 3 minutes
49. Irving H. Sher (Part 2) 2 minutes 38 seconds
50. Using abstracts and changes in the company 2 minutes 49 seconds
51. Working with the patent office and the start of 'Index Chemicus' 2 minutes 49 seconds
52. 'Index Chemicus' 1 minute 32 seconds
53. Using molecular formula for retrieval and citations of my work 5 minutes 22 seconds
54. Promoting 'Current Contents'; the FASEB meeting in Atlantic City 6 minutes 11 seconds
55. Attitudes of the not for profit organisations 2 minutes 7 seconds
56. The 1961 International Congress of Biochemists in Moscow 5 minutes 46 seconds
57. George Vladutz and VV Nalimov 4 minutes 17 seconds
58. Russian colleague's and travelling on the Trans-Siberian Railway 6 minutes 54 seconds
59. Eastern European readership 5 minutes 7 seconds
60. 'Citation Classics' 3 minutes 43 seconds
61. A job offer and teaching at the University of Pennsylvania 3 minutes 6 seconds
62. Sharing information and encyclopedists 4 minutes 43 seconds

63. 'The Atlas of Science' (part 1) 2 minutes 59 seconds
64. 'The Atlas of Science' (part 2) 2 minutes 2 seconds
65. Algorithmic and historiographic analysis 6 minutes, 38 seconds
66. The future of open access and retractions in citations 5 minutes, 1 second.
67. Duplication in research and a citator for patents 4 minutes, 40 seconds.
68. Citing in patents and papers 5 minutes, 52 seconds.
69. Errors and how they effect retreival 3 minutes, 1 second.
70. The mathematics in papers today 1 minute, 31 seconds.
71. H-indexes and impact factors 3 minutes, 37 seconds.
72. Communicating science 2 minutes, 55 seconds.
73. Getting your kids into science and the role of class in science 2 minutes, 19 seconds.
74. Interest in information science; grants and awards 8 minutes, 8 seconds.
75. Hit lists and baseball cards for science 3 minutes, 11 seconds.
76. The future; information Nirvana 1 minute, 47 seconds.
77. The economic issues around open access 4 minutes, 37 seconds.
78. Citations as currency 2 minutes, 24 seconds.
79. Big science and how things are changing 6 minutes, 56 seconds.
80. ASCA selective dissemination system 7 minutes, 6 seconds.
81. What scientists want 4 minutes, 42 seconds
82. Summing up my career 3 minutes 42 seconds

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The Evolution of Journal Citation Reports : An Interview with Dr. Eugene Garfield

50 Years of Citatioon Indexing : A visit with Dr. Eugene Garfield

Bilal, Dania "Reminiscences, Reflections, and Flotsam: an informal conversation with Dr. Eugene Garfield"

SIS Symposium, University of Tennessee at Knoxville, TN. March 23, 2011 http://160.36.161.128/UTK/Viewer/?peid=1fa582f53c4347458858f0106c7797fe

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Institute for Scientific Information Philadelphia, PA on 16 November 1987, p.1-

39.
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Eugene Garfield and Joshua Lederberg

INTERVIEW with Eugene Garfield

A Lifetime of Achievement and Still Going Strong

Eugene Garfield, known by many as the "Father of Scientometrics and Bibliometrics," received the 2006 Online Information Lifetime Achievement Award Nov. 29 in London. The International Information Industry award paid tribute to Garfield's more than half-century of leadership, innovation, and work in the information industry. In a nutshell, he basically revolutionized scientific research with his concept of citation indexing and searching.

At 81, Garfield is still going strong. As the chairman emeritus of Thomson Scientific, he still maintains a busy schedule of speeches and presentations at conferences and symposia. His schedule is filling up fast for 2007, so if he has any inkling of slowing down, he's not letting on yet. When asked if he has any plans to retire, Garfield is quick to say, "What would I do?" He said he tried golfing once, but he came back to the work that he obviously loves to do.

Eugene Garfield accepts the Online Information Lifetime Achievement Award at the 2006 International Information Industry Awards in London.

Garfield thanked Online Information, colleagues, professional communities, friends, and especially his family for their continued support.

Garfield originally started out in chemistry. As a chemistry graduate of Columbia University, he signed on to help with an indexing project at The Johns Hopkins University in 1951. He turned his attention to developing bibliographic citations as viable options to conventional indexing methods. He tested his theory by publishing his own weekly bulletin called *Current Contents* (a table of contents from scientific journals). His fellow scientists saw immediate value in it.

One of the pivotal points for Garfield came in the early 1950s after he read the 1945 article "As We May Think" in *The Atlantic* written by Vannevar Bush. The article expressed Bush's vision of creating a collective memory by recording people's information trails through a device called a Memex that could capture the useful trails through the common record. Something clicked with Garfield.

Garfield's concepts organized the scientific landscape. Back in the early 1950s, "[t]here was no such thing as an information industry," he said. "I've said this over and over again, most of the ideas that I have thought of in some way or another were in … 1951 and 1953. Those are the years that changed my life, and my career especially."

By 1962, Garfield had launched his company ISI (Institute for Scientific Information) and began publishing the *Genetics Citation Index* on behalf of the U.S. National Institutes of Health. He followed a similar strategy in 1964 through ISI with the publication of the *Science Citation Index* (*SCI*), which indexed 613 journals and included 1.4 million citations in a five-volume print edition. *SCI* morphed into Web of Science, which now provides information from 9,000 journals.

The list of his accomplishments spans decades and volumes. A prolific writer and editor, he has published more than 1,000 weekly essays in *Current Contents* (which is still an essential component for clinical research and research labs) and has published and edited more than 5,000

After the awards presentation, the Royal Lancaster Hotel opened the floor to dancing.

Eugene Garfield, chairman emeritus, Thomson Scientific

works by authors in *Citation Classics*. He started *The Scientist* in 1986, a biweekly newspaper for research professionals about news and developments that pertain to scientists. His latest project is developing HistCite (algorithmic historiography), an innovative search that can combat "information overload." Information overload is something Garfield considers a key challenge to the information industry today. He said that we have an increased need for greater differentiation

> **Information overload is something Garfield considers a key challenge to the information industry today.**

in information, and finding the right information is sometimes like trying to find a needle in a haystack.

When it came to citing the highlights in his own career, Garfield just smiled. A true Renaissance man, Garfield has been a chemist, an information scientist, an editor, a publisher, and a database producer. "The reason I had a reputation as a writer is because I had a good staff," he said. But he continued: "I tell you that among scientists, I was known not for my *Science Citation Index*, but rather for the *Current Contents*. The influence of *Current Contents* was ignored by historians."

Since not everyone accepted his innovations and ideas, he took it all in stride and kept right on going: "Like in any other career, you just have to move on," he said. "You just have to ignore the naysayers."

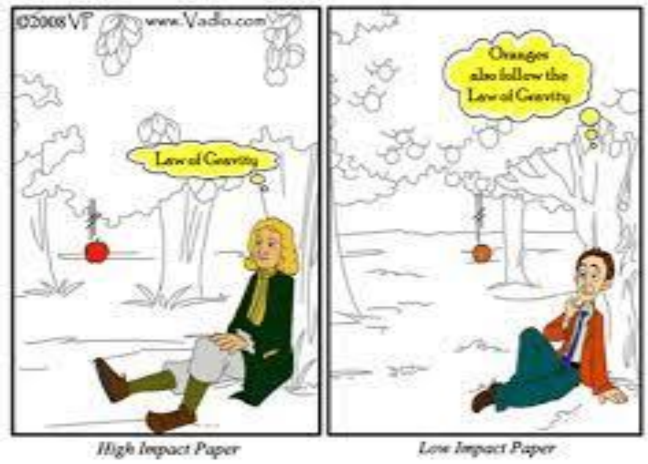
The day after Garfield accepted his lifetime achievement award in London, he spent time at the Thomson Scientific stand at the Online Information conference autographing the profile of him in the glossy Thomson Scientific booklet, *Thomson Scientific: Information to Change Your World*. The long line of autograph seekers was wrapped around the perimeter of the Thomson booth waiting for a chance to meet and chat with the citation legend.

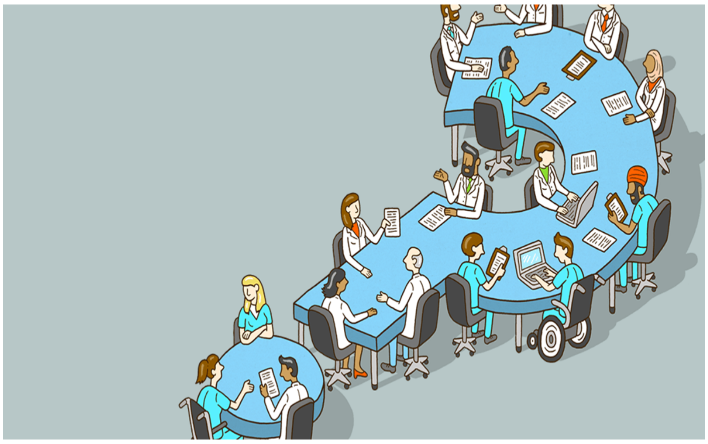
—*B.B.*

PUBLISHING

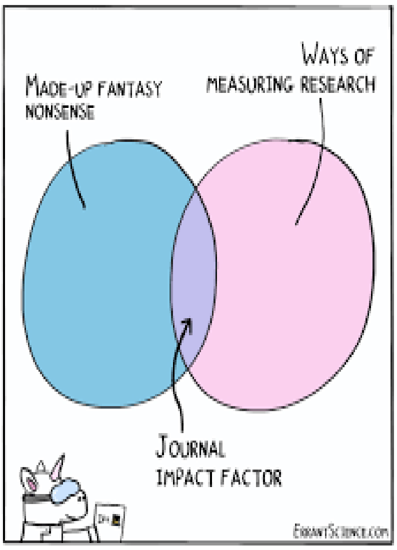
through

CARTOONS





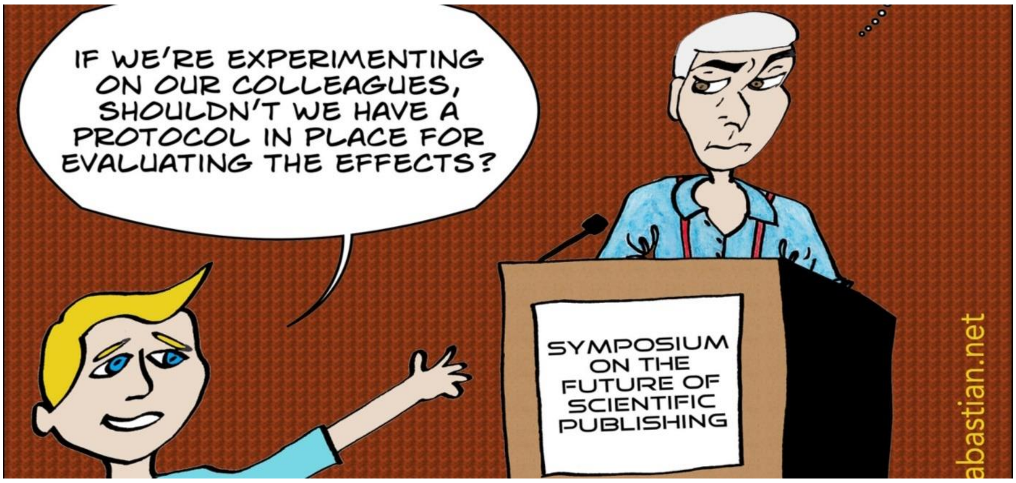
What's the best journal for my paper?

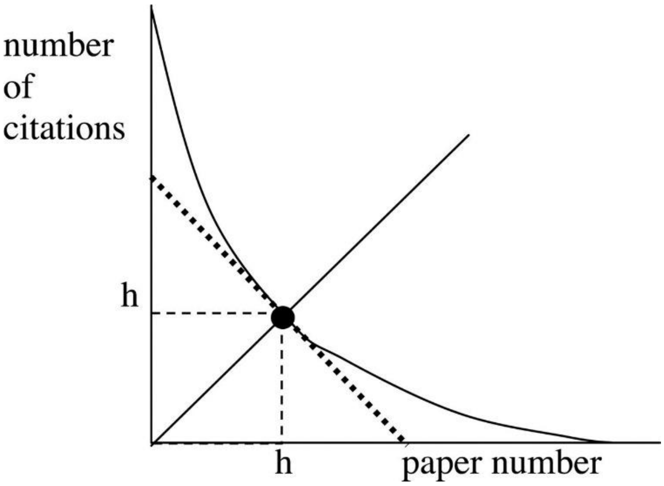



DATA REPOSITORY
submissions welcome


NO TO DELAY
OUT WITH EDITORS!
DOWN WITH JOURNALS!
OUT WITH SECRET PEER-REVIEW


BIAS?! AT OUR JOURNAL?
WE GOT RID OF THAT YEARS AGO!
EXACTLY! WE'RE DOUBLE-BLIND.


IF WE'RE EXPERIMENTING ON OUR COLLEAGUES, SHOULDN'T WE HAVE A PROTOCOL IN PLACE FOR EVALUATING THE EFFECTS?
SYMPOSIUM ON THE FUTURE OF SCIENTIFIC PUBLISHING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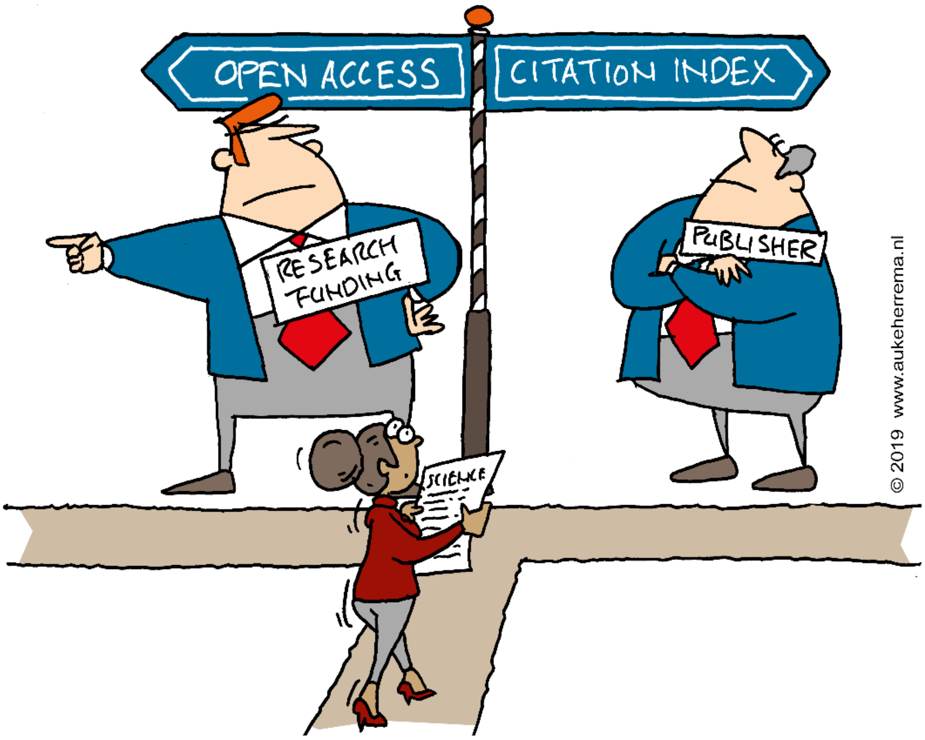
OPEN ACCESS
CITATION INDEX
RESEARCH FUNDING
PUBLISHER
SCIENCE
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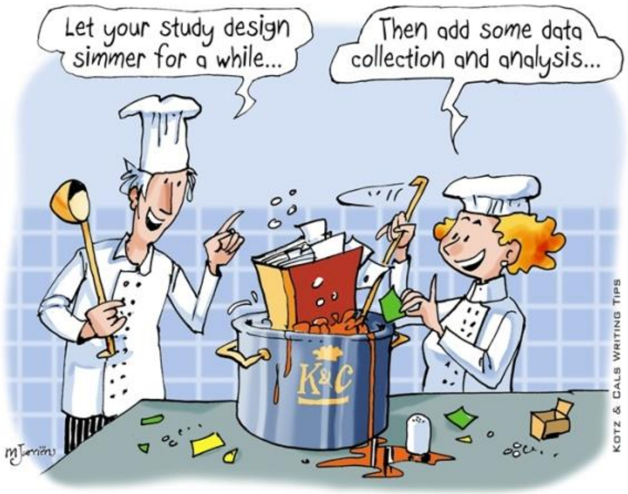
Tip 2 - Title and abstract: sell your paper!

Tip 8 - References: always go back to the original source!

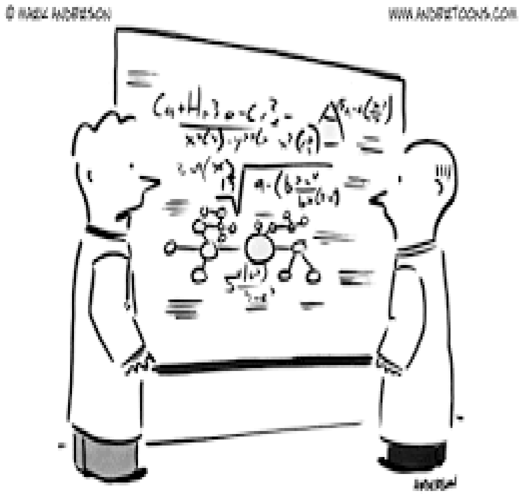
Tip 10 – Choice of journal: define a list of target journals!

Tip 5 – Results: present findings without interpretation!

Tip 6 – Discussion: be frank in acknowledging limitations!



Tip 4 – Methods: provide a cookbook with the study's ingredients!



"I don't know, it's a little formulaic."

"Welcome to the co-author's party!
You're number twenty-one!"

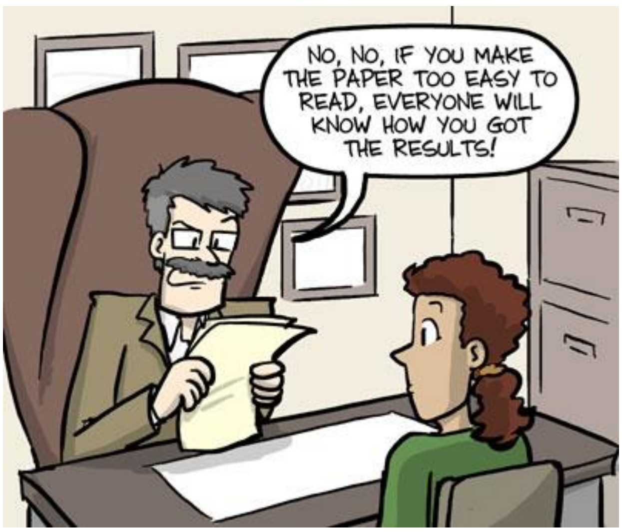
Tip 11 - Submitting a paper: write a convincing cover letter!

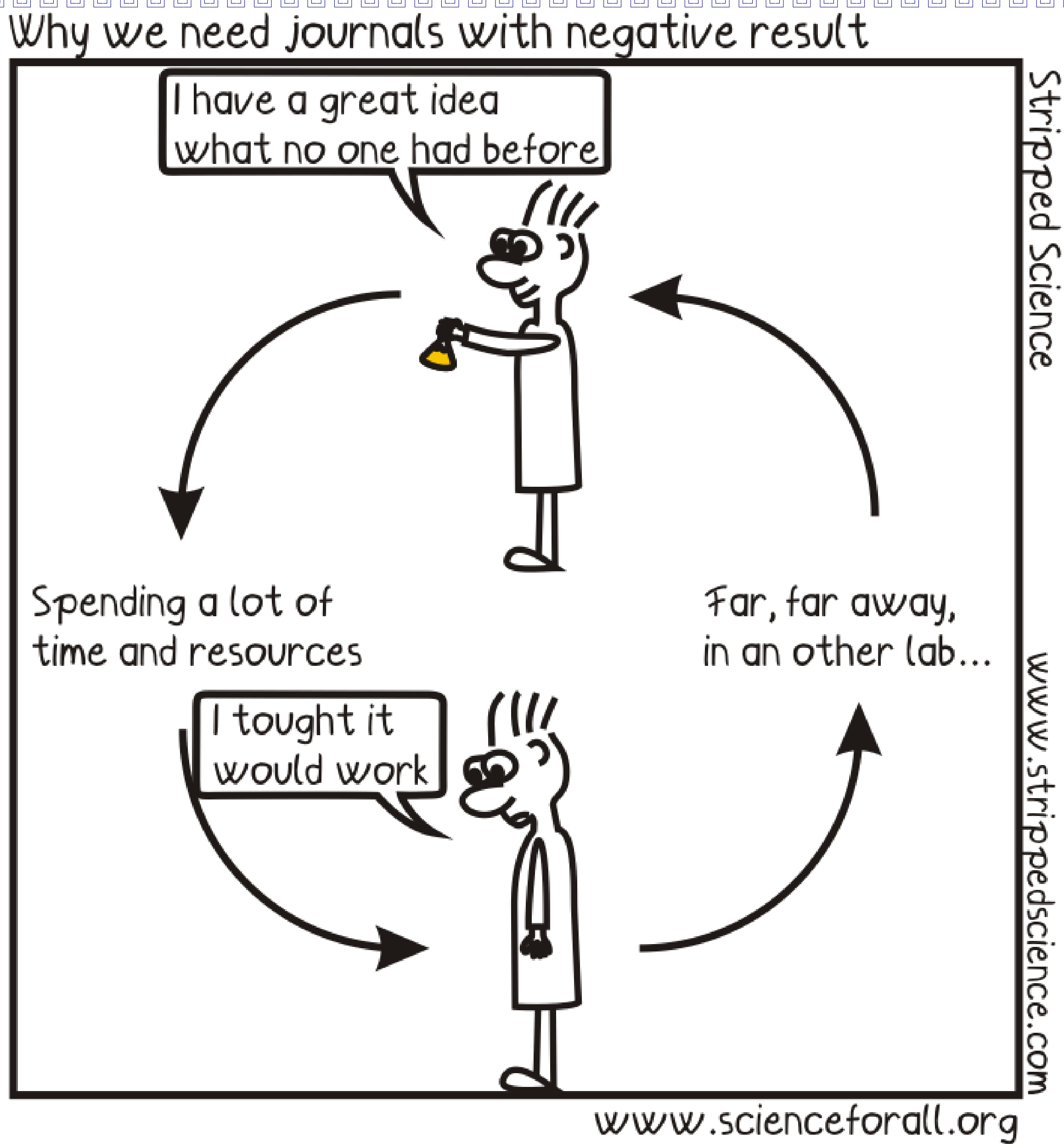
Tip 12 - Responding to reviewers: don't get frustrated!

Tip 3 - Introduction: work on that funnel shape!

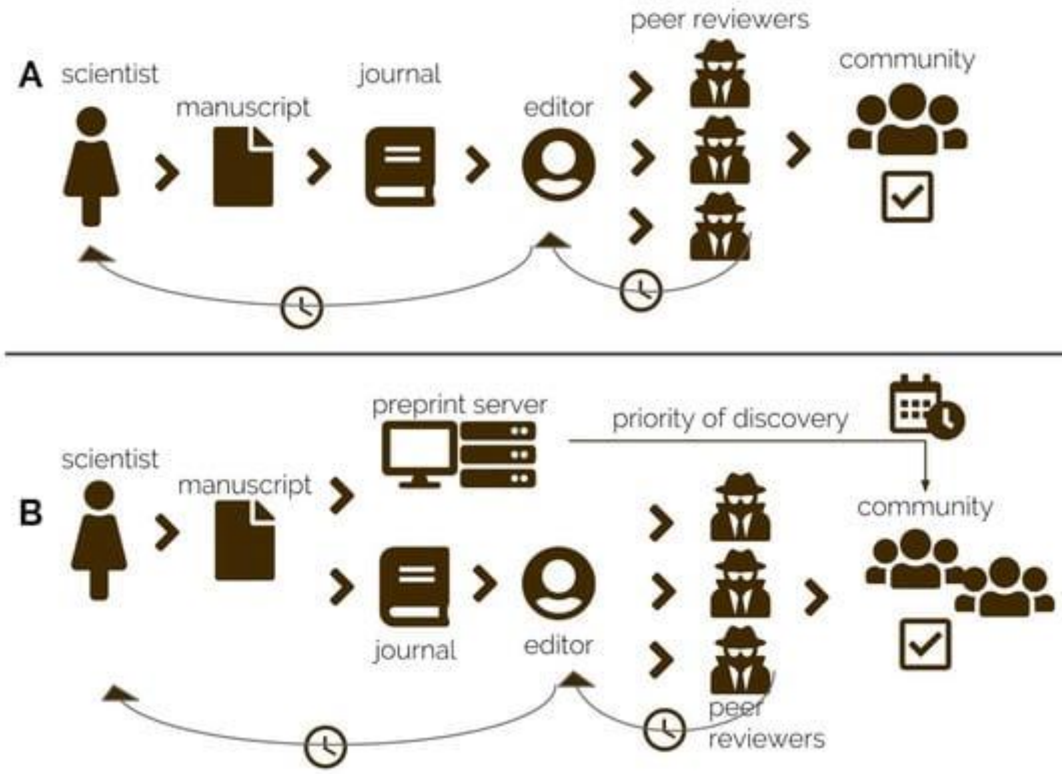
Tip 1 – How to get started: choose the optimal environment!

Each author should take responsibility for a specific part of the work.





"According to the latest scientific research, the human body is 60% water and 40% stress."



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Reproducibility: A tragedy of errors

Building the 21st century scientist

Decision makers need constantly updated evidence synthesis

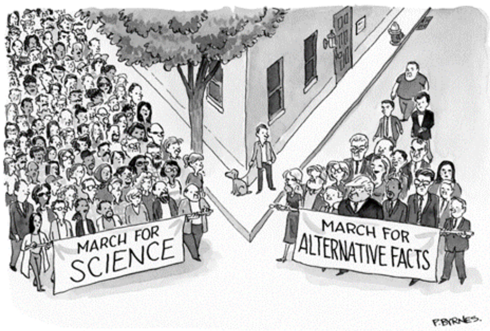
Tip 9 Authorship: discuss it within the team!

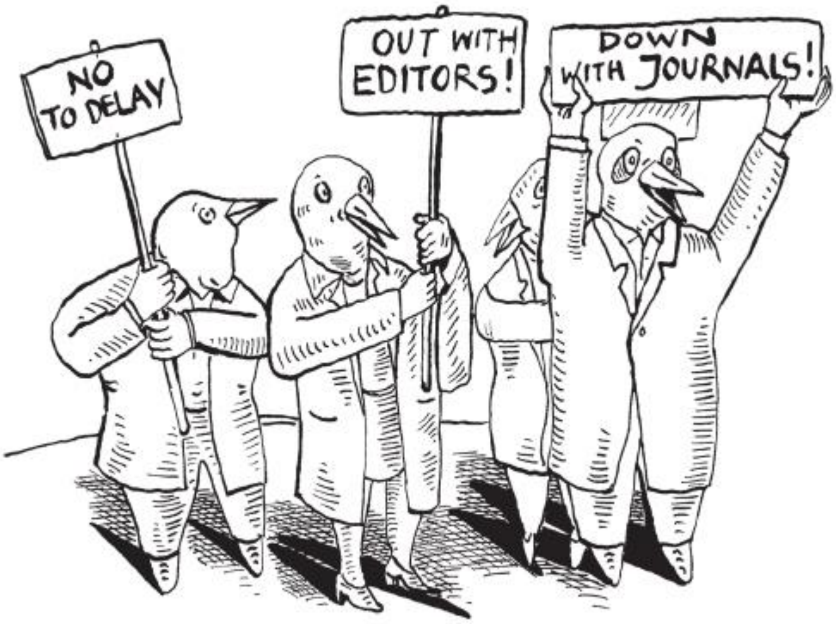
"I don't believe I've ever seen a scientific paper defended quite as vigorously as this one!"

Tip 7 - Tables and figures: make them self-explanatory!

"It looks like we've created Super Resistant Rat."

"It's important to learn math because someday you might accidentally buy a phone without a calculator."





Indian Journals

in

Web of Science

Here three web links are given which may lead the research scholars to several important Indian Journals that are Scopus-indexed and/or in Web of Science.

[A] https://www.wosjournal.com/country.php?id=India

List of Web of Science Journals of India Publishers [355 Journals]

[B] https://www.journalsindexed.com/2013/04/scopus-sources-journal-of-india.html

Scopus indexed Indian journals, all Indian journals listed in Scopus base.

[C] https://www.ardaconference.com/blog/list-of-web-of-science-indexed-journals/

Similar to Scopus, Web of Science is a website that provides access based on subscriptions to the database that comprises comprehensive citation data of different academic fields. It is one of the best citation websites known in the field of science and technology. With contains over 33,000 journals, books, and citation databases along with conference proceedings, a web of science parents that work back to the 1900s. So, if you are getting your work published in the Web of Science journals, it is a remarkable achievement in your academics.

Some things and details are to be taken into consideration before getting your work published in a journal such as Journal Impact Factor. Getting a journal publication by attending an international conference is one way to go. Highly reputed and enshrined with innovations, discoveries and knowledge in the fields, here are a few Web of Science Journals.

[D] https://www.ilovephd.com/ugc-care-list-of-science-journals/

The UGC-CARE List has classified into i) Sciences ii) Social Sciences iii) Arts and Humanities and iv) Multidisciplinary based on All Science Journal Classification (ASJC) codes, which are created and maintained by Scopus (Elsevier Science). In this article, all Group-I UGC CARE list of journals in Science are included.

[E] https://www.ilovephd.com/indian-journals-indexed-in-web-of-science-ugc-care-list-group-a/

The University Grants Commission (UGC) aspires to stimulate and empower Indian academia through its "Quality Mandate". A public notice was issued by the UGC, to announce the establishment of a dedicated Consortium for Academic and Research Ethics (UGC CARE journals List) to carry out this mandate.

- To promote quality research, academic integrity and publication ethics in Indian universities.
- To promote high-quality publications in reputed journals that would help in achieving higher global ranks.
- To develop an approach and methodology for the identification of good quality journals.
- To prevent publications in predatory/dubious/sub-standard journals, which reflect adversely and tarnish the image of Indian academia.
- To create and maintain a "UGC-CARE Reference List of Quality Journals" (UGC-CARE List) for all academic purposes.

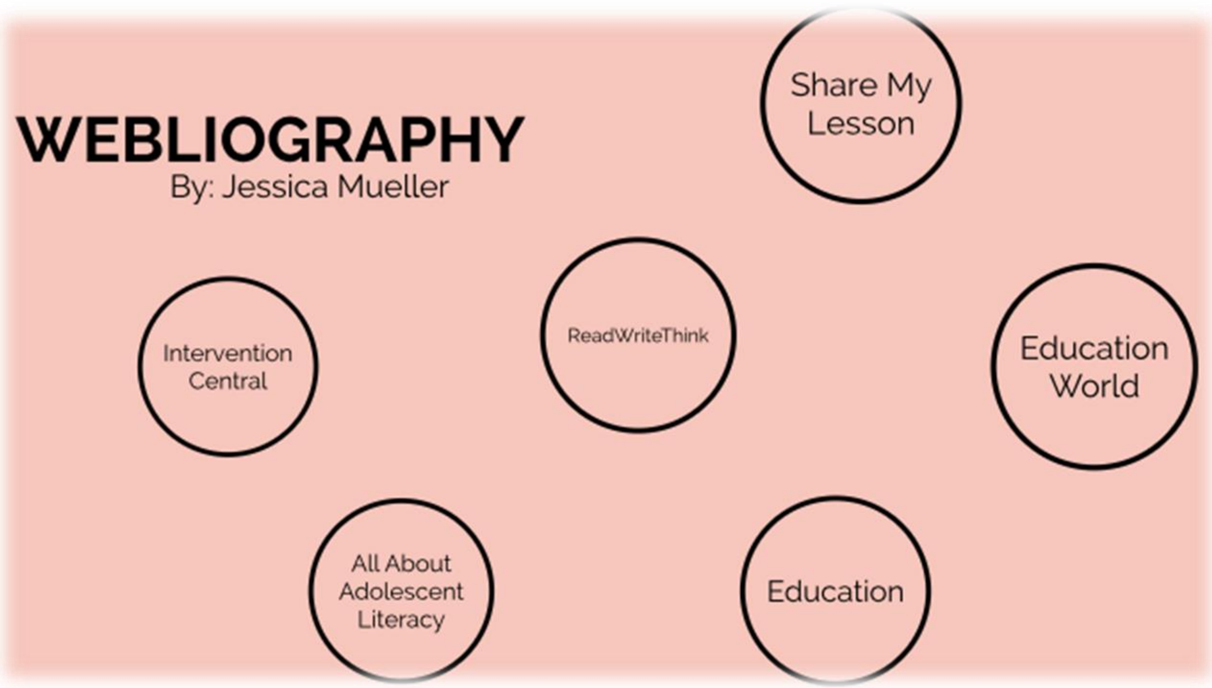
Annotated

Webliographies

No.	Webliography - Annotated
01	http://www.garfield.library.upenn.edu/ Comprehensive and exhaustive website of Prof Dr Eugene Garfield, containing everything about him – life, family, his interviews, his contributions, awards and honours, SCI, ISI, awards his name, his memberships in academic and scientific associations, etc.,
02	http://www.garfield.library.upenn.edu/pub.html Comprehensive bibliography covering his articles, papers, essays, presentations, between the years 1952 & 2005
03	http://www.garfield.library.upenn.edu/autobiographical.html His autobiographical essays covering the entire family from his birth to his death.
04	https://www.isko.org/cyclo/citation Providing detailed information about citation – the idea of citation databases, principles and design of citation indexes, classification of citation index, studies of citation behavior, etc.,
05	https://www.sciencedirect.com/science/article/pii/S1751157717301463 **Elsevier** : Obituary : >> A tribute to Eugene Garfield: Information innovator and idealist
06	https://www.frontiersin.org/articles/10.3389/frma.2018.00014/full An Essay by Alexander M. Grimwade : Eugene Garfield - 60 Years of Invention and Innovation
07	https://www.msuniv.ac.in/Download/Pdf/416c2092430b462 List of science citation indexed journals [9500 journals]
08	https://www.ilovephd.com/top-100-journals-in-the-world-with-impact-factor/ List containing Top 100 Journals in the World with Highest Impact Factor 2023
09	https://researchguides.uic.edu/if/impact Overview of h-index, Eigen factor, Impact Factor (IF), Journal Citation Reports, Citation Analysis, and other tools.
10	http://www.garfield.library.upenn.edu/interviews.html Web of Stories: His interviews [audio & video]
11	https://encyclopedia.pub/entry/87 "Eugene Garfield's Ideas and Legacy" – An article by Baykoucheva, S.
12	https://www.nature.com/articles/543492a

	"Eugene Garfield (1925–2017) - Inventor of the Science Citation Index" :::: Published in *Nature* 543, 492 (2017), published on 23 March 2017
13	https://www.sciencedirect.com/topics/social-sciences/eugene-garfield Interviews with Eugene Garfield <:> By several scientists
14	https://cen.acs.org/policy/publishing/Impact-factor-creator-chemical-information/96/i15 Speakers at the recent ACS national meeting celebrated how Garfield conceived of and developed information tools now integral to the modern scientific enterprise
15	https://www.historyofinformation.com/detail.php?id=817 "Eugene Garfield Starts the Science Citation Index" <:> An Article
16	https://www.mdpi.com/2304-6775/7/2/43 "Eugene Garfield's Ideas and Legacy and Their Impact on the Culture of Research" <:> An Article by Svetla Baykoucheva, STEM Library, University of Maryland, College Park, MD 20742, USA
17	https://research.com/u/eugene-garfield Rare information and other details about Prof Dr Eugene Garfield.
18	https://www.researchgate.net/publication/228457387_The_impact_of_Eugene_Garfield_through_the_prism_of_Web_of_Science "The impact of Eugene Garfield through the prism of Web of Science: An Article by Peter Jacso, University of Hawai
19	https://www.academia.edu/7297145/Eugene_Garfield_A_Scientometric_Portrait "Eugene Garfield A Scientometric Portrait" – An Article by Dr SL Sabgam and other rated papers.
20	https://www.leydesdorff.net/garfield_historiography/ "Eugene Garfield and Algorithmic Historiography: Co-Words, Co-Authors, and Journal Names" <:> An Article by Loet Leydesdorff, University of Amsterdam, Amsterdam School of Communications Research (ASCoR), Kloveniersburgwal 48, 1012 CX Amsterdam, The Netherlands.
21	https://bid.ub.edu/en/37/urbano.htm *"Eugene Garfield: innovator of the bibliographic control and entrepreneur with a cause" <:> An Article by Cristóbal Urbano Faculty of Library and Information Science, Universitat of Barcelona.* Laudation delivered by Cristóbal Urbano, lecturer at the Faculty of Library and Information Science, during the ceremony in which Eugene Garfield was awarded the University of Barcelona's honorary degree the Doctor honoris causa, on 14 June 2016 in the Paranymph Hall of this university's Historic Building.
22	https://guides.library.cornell.edu/impact/getting-started

	"Measuring your research impact: Getting Started" <:> This guide provides an introduction to the various metrics used to measure researcher and journal impact. [Cornell University Library]
23	https://guides.library.cornell.edu/impact/jcr "Measuring your research impact: Journal Citation Reports (JCR)" <:> This guide provides an introduction to the various metrics used to measure researcher and journal impact. [Cornell University Library]
24	https://libguides.lib.uct.ac.za/tracking_your_academic_footprint/journal-citation-reports "Research Impact Library Guide: Journal Citation Reports (Thomson Reuters)" <:> The guide covers ways you can measure your impact as a researcher.
25	https://www.academia.edu/11848842/List_of_Science_Citation_Index_SCI_journal?email_work_card=view-paper The Science Citation Index (SCI) is a citation index originally produced by the Institute for Scientific Information (ISI) and created by Eugene Garfield. It is now owned by Thomson Reuters. The larger version (Science Citation Index Expanded) covers more than 6,500 notable and significant journals, across 150 disciplines, from 1900 to the present. A citation index is a kind of bibliographic database, an index of citations between publications, allowing the user to easily establish which later documents cite which earlier documents. The impact factor (IF) of an academic journal is a measure reflecting the average number of citations to recent articles published in that journal. Elsevier publishes Scopus, available online only. ISI (now part of Thomson Reuters) publishes the ISI citation indexes in print and compact disc. Indian Citation Index is an online citation data which covers peer reviewed journals published from India.



The Impact of Eugene Garfield through the prism of WoS

Peter Jacso

Professor, Department of Information and Computer Sciences,
University of Hawai'i at Mãnoa, Honolulu

Email: jacso@hawaii.edu

The paper attempts to quantify the impact of the scholarly publishing activity of Dr. Eugene Garfield, the founder and Chairman Emeritus of the Institute for Scientific Information, the father of citation indexing of academic literature. In the project the most current version of the Web of Science system was used with five of its component databases. It provides the most comprehensive, but still not complete, set of cited reference enhanced bibliographic records for Garfield's journal articles, conference papers, reviews, essays, commentaries, letters to the editors, and for the 6,500 citations that his publications received, and could be credited to a matching record in the master file of Web of Science. The paper also analyzes the effect of the fact that his books, book chapters, technical reports are not considered in calculating the impact measures reported by the informative Citation Report module of Web of Science, and the consequences of the approximately 7,000 "stray" and "orphan" references received by all his works that would more than double Garfield's traditionally measured impact factor, the average rate of citations per publication, for his entire ouvre. There is a short discussion about improvements that should be made in the citation matching algorithm that –in his case- distorts the distribution of citations among his more than 1,000 essays and commentaries in Current Contents, Current Comments and The Scientist for reason of an exceptional bibliographic and chronological-numerical designation pattern. Suggestions are made to make the browsing, searching, sorting, and processing of the reference entries and cited reference counts in the separate index file of cited references of Web of Science, which in his case amount to a combination of more than 13,300 matching, orphan and stray references in the more than 3,300 reference entries to his publications that were cited at least once.

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The impact of Eugene Garfield through the prism of Web of Science

Peter Jacso
Professor, Department of Information and Computer Sciences, University of Hawai'i at Mãnoa, Honolulu
Email: jacso@hawaii.edu

The paper attempts to quantify the impact of the scholarly publishing activity of Dr. Eugene Garfield, the founder and Chairman Emeritus of the Institute for Scientific Information, the father of citation indexing of academic literature. In the project the most current version of the Web of Science system was used with five of its component databases. It provides the most comprehensive, but still not complete, set of cited reference enhanced bibliographic records for Garfield's journal articles, conference papers, reviews, essays, commentaries, letters to the editors, and for the 6,500 citations that his publications received, and could be credited to a matching record in the master file of Web of Science. The paper also analyzes the effect of the fact that his books, book chapters, technical reports are not considered in calculating the impact measures reported by the informative Citation Report module of Web of Science, and the consequences of the approximately 7,000 "stray" and "orphan" references received by all his works that would more than double Garfield's traditionally measured impact factor, the average rate of citations per publication, for his entire ouvre. There is a short discussion about improvements that should be made in the citation matching algorithm that –in his case- distorts the distribution of citations among his more than 1,000 essays and commentaries in *Current Contents, Current Comments* and *The Scientist* for reason of an exceptional bibliographic and chronological-numerical designation pattern. Suggestions are made to make the browsing, searching, sorting, and processing of the reference entries and cited reference counts in the separate index file of cited references of Web of Science, which in his case amount to a combination of more than 13,300 matching, orphan and stray references in the more than 3,300 reference entries to his publications that were cited at least once.

Introduction

The 85th birthday of Eugene Garfield, provides yet another opportunity to pay homage to his intellect, influence and inspiration. Ten years ago more than 30 of the most respected scientists, practitioners and educators who worked with and/or used extensively Eugene Garfield's citation indexes and several other unique databases in various incarnations, teamed up to publish The Web of Knowledge: A Festschrift in Honor of Eugene Garfield[1], whom I consider to be a contemporary renaissance man, a visionary, an indefatigable researcher, and a fabulous story teller.

Time and again I have re-read many of the papers in the Festschrift[2-13]. It was the most appropriate birthday present to him (and to his friends, colleagues, and disciples) to celebrate the festive event both in content and format as the relatively seldom used general material designator (GMD) of the Anglo-American Cataloging Rules indicated in the subtitle.

It was not merely a book of 565 pages with 26 substantial, thought and emotion provoking articles, but indeed a superb manifest of festive scholarly writing, a bouquet of academic contributions that don't wilt - written for the special occasion, competently edited (arranged in flower-shop lingo) by Blaise Cronin and Helen Barsky Atkins, and published (gift wrapped and delivered) on time by Tom Hogan, the founder and president of Information Today, Inc. to thousands of friends and readers of Gene Garfield at Hogan's usually very reasonably set $50 price (that was lower than ordering two articles of similar caliber from academic publishers or through document delivery services with restricted usage stipulations).

Five years ago, for Garfield's 80th birthday, I had the privilege to be the humble part[14] of another outstanding team led by the leading Indian scientometrician, Subbiah Arunachalam as special editor, whose works I often used in my research[15-20], to publish a special section of Current Science. This was followed by an invitation to be a contributor to the special booklet appendix of *The Scientist*, with a short divertimento piece - to pay homage to Garfield's humanist side[21] through his writings, not (directly) associated with science, but related to global human issues with links to 38 such essays of Garfield from the open access version that bears the correct spelling of my name << http://www2.hawaii.edu/~jacso/extra/80/.

The invitation to write for the special issue of Annals of Library and Information Studies on the occasion of Garfield's 85th birthday was irresistible, and a good excuse to immerse again into his articles, editorials,

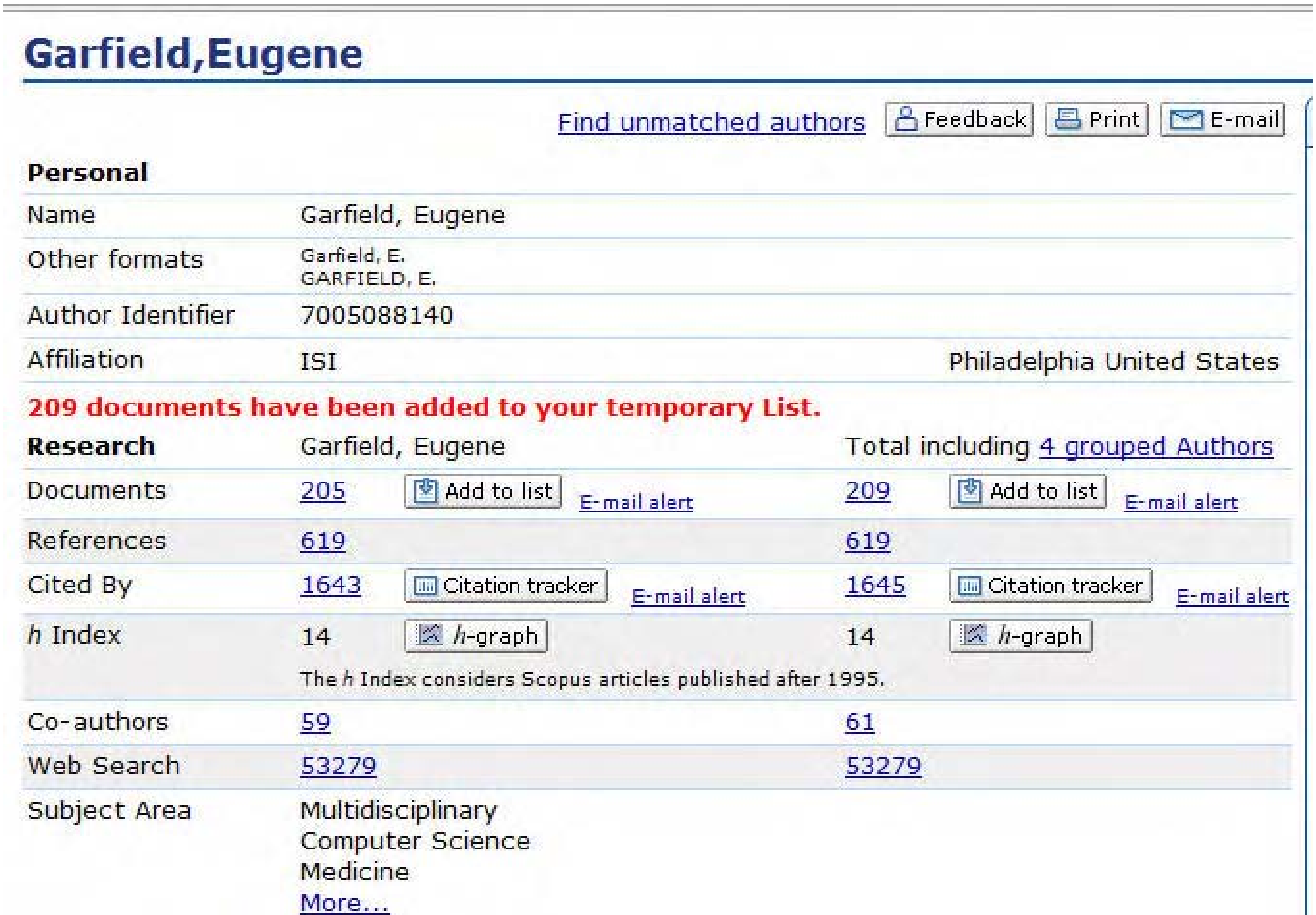


Fig. 1 — Garfield's personal profile page in Scopus

commentaries, and essays. I could not re-read all of his 1,500+ publications, but browsed through a great many of them, as well as our e-mail correspondence. It is topping on the cake that writing a personal, subjective tribute I may have some liberty of style instead of being forced to use the studied scholarly style that Garfield himself so perfectly and consistently avoided.

As a warm-up for this project, I also reminisced about our personal meetings and discussions on those occasions when he stopped over in Hawaii for a day or two on his way to Novosibirsk or Seoul, to work with the next generation of researchers and software developers on HistCite (his unique citation analysis software), or to do a conference keynote speech, and to gracing my students and me with a guest lecture or just "talking story" as they say in Hawaii. One of his most appealing traits is that he can talk story and write about the most complicated science issues as well as the most mundane topics in a way that appeals to a very wide audience from undergraduate students to senior professors and researchers.

For this paper, I decided to try to give a tangible, reproducible account of his impact through various impact indicators that are automatically reported or can be calculated from the Web of Science database. Scopus was not an appropriate alternative in spite of its many remarkable, state of the art interface and software features, because it had master records for only a very small, 13-14% subset of his papers, and citations merely from 1996 onward, which obviously has a very distorting effect on a scholar's performance who started publishing and get cited more than four decades before 1996.

Google Scholar had a much broader coverage of his writings, but it is limited to showing 1,000 records, and it still has serious problems with essential issues (phantom author names, publication years and citations) that are critical for quantitative evaluation

of publishing performance and impact[22]. Not even the intelligent third-party programs can help in this regard, except for spotting them more easily through compensating for the lack of elementary features in Google Scholar such as sorting the results correctly by times cited and by several other data elements, marking and transferring records for further processing.

WoS was tested for this project from February to mid-June, 2010. The hit count for Garfield's papers has not changed, but the number of citations, and thus the indicators involving citations did increase continuously. Doing such an analysis is like nailing a jelly to the wall. This explains why some of the indicator values are slightly different on different screenshots or in the text. When necessary, I will indicate when the search was made. One may wonder why this research was important when there is ResearcherID, a useful software tool for Web of Science users to learn about much of the information that I tried to compile and analyze. Well, while our scores in terms of the basic indicators (total papers published, total citations received, average citations per paper, and the h-index) are almost identical, there are very significant differences in those metrics that offer a refined view of the impact of Garfield as mirrored by the citing authors, journals, institutional and country affiliations.

In addition, my numbers from the same WoS database show the results for the entire population of citations that match master records, while ResearcherID shows only the purportedly top 20 most citing authors, journals, painting quite a different picture from the same data source. I am not saying that ResarcherID's rank lists and scores are not correct, but its appropriate interpretation needs further information. While the basic metrics are obviously calculated from the WoS master records in the entire database based on the bibliography of Garfield as of April 2008, the citation analyses seem to be based only on a subset of the citing papers that matched his master records in WoS. It is clear from the total citations chart on the next figure that specifically mentions that the past 20 years data are shown, there is no similar explanation for the analysis of citing papers by top 20 authors, institutions, countries, subject area, sources, etc.

Garfield's ResearcherID badge

Eugene Garfield's own ResearcherID badge tells a lot (but not all) about his scholarly productivity and impact. It is generated from the Web of Science

Fig. 2 — Garfield's ResearcherID badge on May 8, 2010

Fig. 3 — Garfield's ResearcherID badge on June 13, 2010

database (WoS) which is far the most comprehensive, measurable, and verifiable inventory of the papers he published and of the citations his works received and could be matched with and attributed to master records in WoS.

I looked up the badge again the day before closing this manuscript in mid-June, to see changes since a good month before. The number of publications still seems 10 records short of what is available in the most complete edition of WoS- both in terms of the components, and of the time span.

I used the combination of the three traditional Citation Indexes (Science, Social Sciences, Arts & Humanities) as well as the recently introduced Conference Proceedings Indexes, without any time limitations or other filters, such as document type, language.

The overlap between the components (when, for example, a journal is covered in more than one of the databases) are automatically eliminated by WoS. The two chemical databases of Thomson-Reuters (Current Chemical Reactions and Index Chemicus) were not included as there are no master records in them related to Garfield's publications. I repeatedly ran several of the queries in WoS from February to mid-June, 2010. The only remarkable change was that the number of citations received kept increasing, due to new citations from papers published in 2010, reaching 6,491 by mid-June (and 6,501 by June 18), when the manuscript was finalized.

This pace of increase is quite remarkable because there are many researchers who do not receive as many new citations to their entire scholarly publishing ouvre even throughout a year.

Then again, Garfield's publishing productivity has been exceptionally high. I did not reproduce all the spreadsheets and charts in the process, because the minor changes throughout the 4-month test period did not modify the essential publishing indicators, and

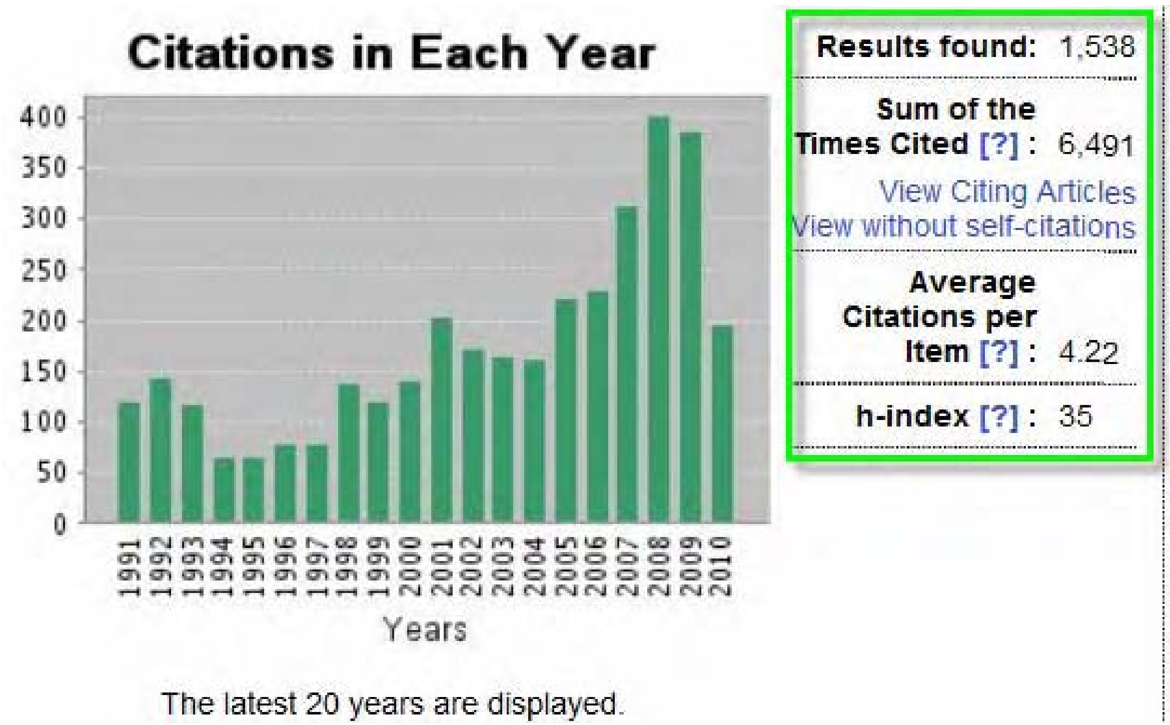


Figure 4. Excerpt from Garfield's Citation Report in WoS on June 13, 2010 The WoS Citation Report also shows (optionally) the citations to Garfield's work for his entire publishing time span as shown in Figure 5. The citation chart also shows an unusual pattern to be discussed later.

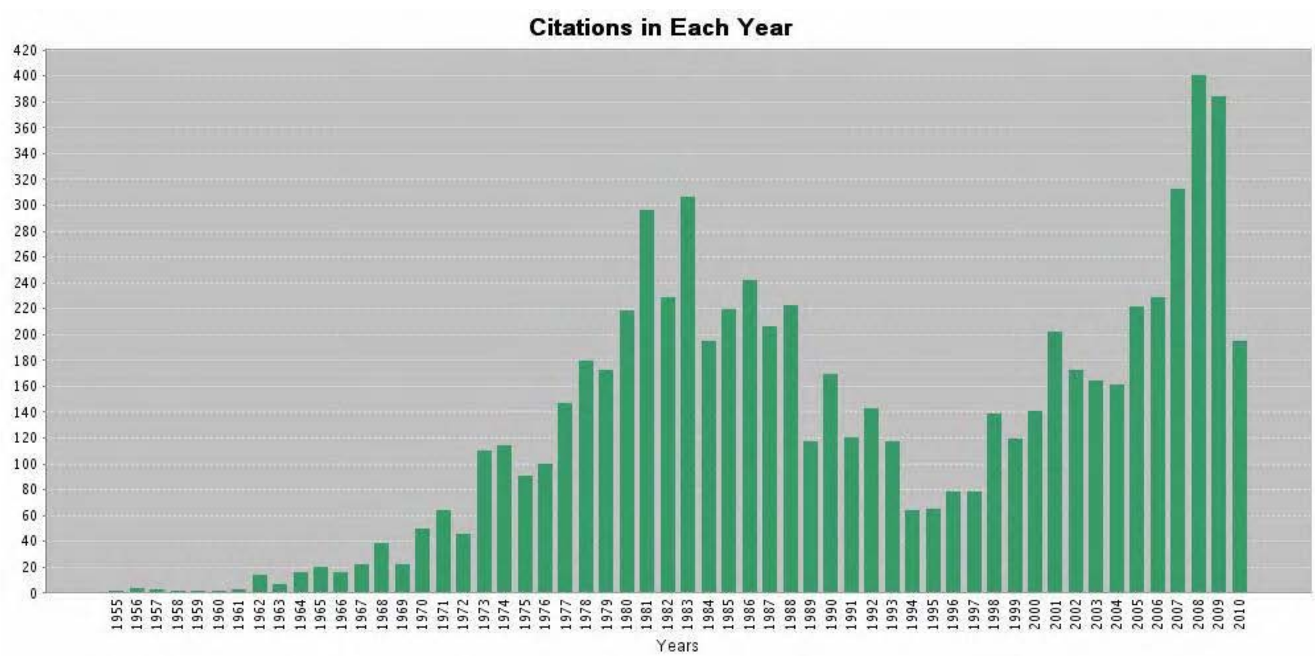


Fig. 5 — Citations received by Garfield since 1955

yielded only minute changes in some of the citedness ratios.

The Citation Report generated on the same day when the ResearcherID badge was updated, shows 21

additional citations because no time limit was applied as opposed to the indicators collected for the ResearcherID, which apparently ignored 10 publications with master records that WoS did count. I could identify 5 of them which were created for Garfield's most recent papers that were apparently not added to the bibliography which is the basis in ResearcherID to collect the data. I could not identify (yet) the other five records available in my set but not in ResearcherID. Not even these 10 records justify the differences between ResearcherID and my findings when it comes to the list and rank order of the citing authors, journals, affiliations.

However, not even the Web of Science product which grew out from Garfield's innovative, much appreciated and criticized and widely used three citation indexing databases for the Sciences, Social Sciences, and Arts and Humanities, can provide full account of his publishing productivity and impact. The reason for this is that not all of his publications have a master record in WoS, and many of the citations received by his works are inaccurate and/or incomplete, and thus are not accounted for, let alone credited to the appropriate master record even if there is one for the cited work. The very imperfect cited referencing of many of the scholarly authors (including this very author), and the maddeningly complicated variations of citation styles, makes any citation-based evaluation just an approximation at best.

Garfield's publication profile

Eugene Garfield with more than 1,500 publications has been one of the most productive (if not the most productive) authors among those whose publications have an entry among the 47.7 million records making up the WoS database as of mid-June, 2010. True, there seems to be several hundred authors with an

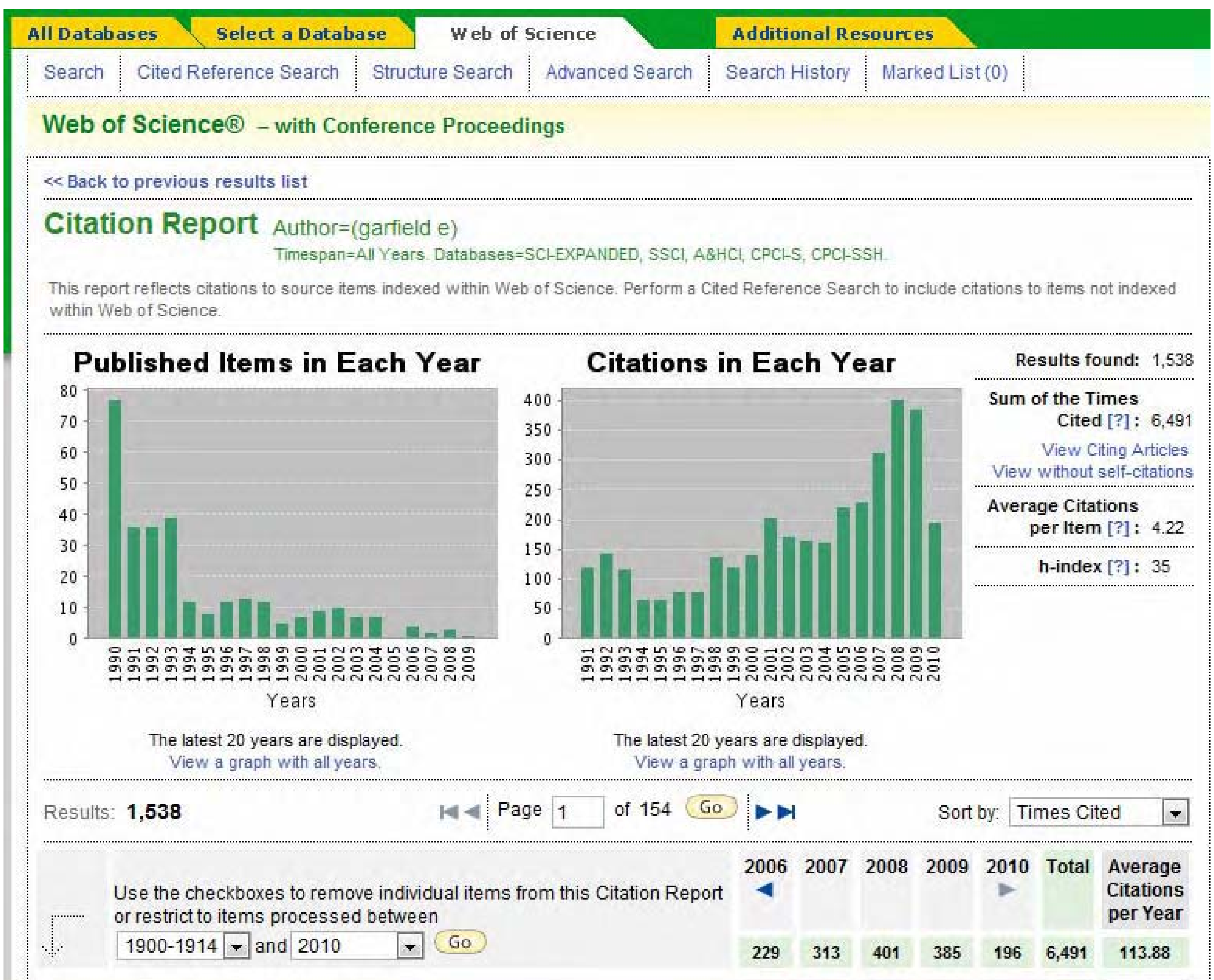


Fig. 6 — WoS Citation Report with key productivity and impact indicators

order of magnitude higher hit counts, but behind the identical last name, first and middle initial(s), there are tens or even hundreds of different researchers, such as those among the 20,000+ “club” members, like the Y Zhangs, J Zhangs, J Wangs, T Suzukis, J Lis, or the 10,000+ club’s members, like the Y Lius, K Tanakas, J Lees, JH Kims, F Nakamuras, A Kumars, I Guptas. Beyond the Chinese, Japanese, Korean and Indian researchers, there are hundreds of researchers from Europe, and North America in the 5,000+ club that are undistinguishable because of the same last name and first (and even middle) initials, such as the A Smithes, R Smithes, R Willamses, J Martins, or M Mullers (WoS records have no accented and other special characters), and close to 3,000 other homonyms.

Using subject categories alleviates the serious problem of homonymity, especially as in WoS 99.5% of the records have at least one subject category assigned – a far better completeness rate than in Scopus and especially in Google Scholar. However, on the average there are 1.9 broad subject categories assigned per items for Garfield’s works, which broadens the scope, and the chance of overlap between two or more authors with the same last name and initial(s). Author affiliation as an additional distinguisher attribute may also help, but this data element are not available in 26% of the WoS records again a better rate than in Scopus. Google Scholar does not offer a field-specific searchable index by affiliation.

Fortunately, there is only one author in the WoS database with the exact last name-first name combination Garfield, E (1,537 times, and once as Garfield.E), and all records are about items published by “our” Eugene Garfield.

Publishing 1,538 papers in 56 years between 1954 and 2009 (the most recent year he published a paper as of mid-June, 2010), indicates very intense writing - publishing on the average nearly 28 papers per year. In addition, he was the solo author of 96% of the papers which is increasingly important considering many of his multidisciplinary papers, and the growing motivation to include more authors, and sometimes “honorary authors” because of the commonly applied whole counting system, that gives credit to every author as opposed to the fractional system, where publications/citations are divided by the number of co-authors.

He had one co-author for 41 papers, two for 14 papers, three for 3 papers, and four for 6 papers. Exceptionally, he was a member of a team of 7-9 authors in four articles.

Actually, he wrote more than 1,538 papers, but some were never published, such as the Machine Methods in Indexing, The Mechanization of Indexing, both in 1952, or the Librarian versus Documentalist, submitted to *Special Libraries* in 1953 (which did not publish it).

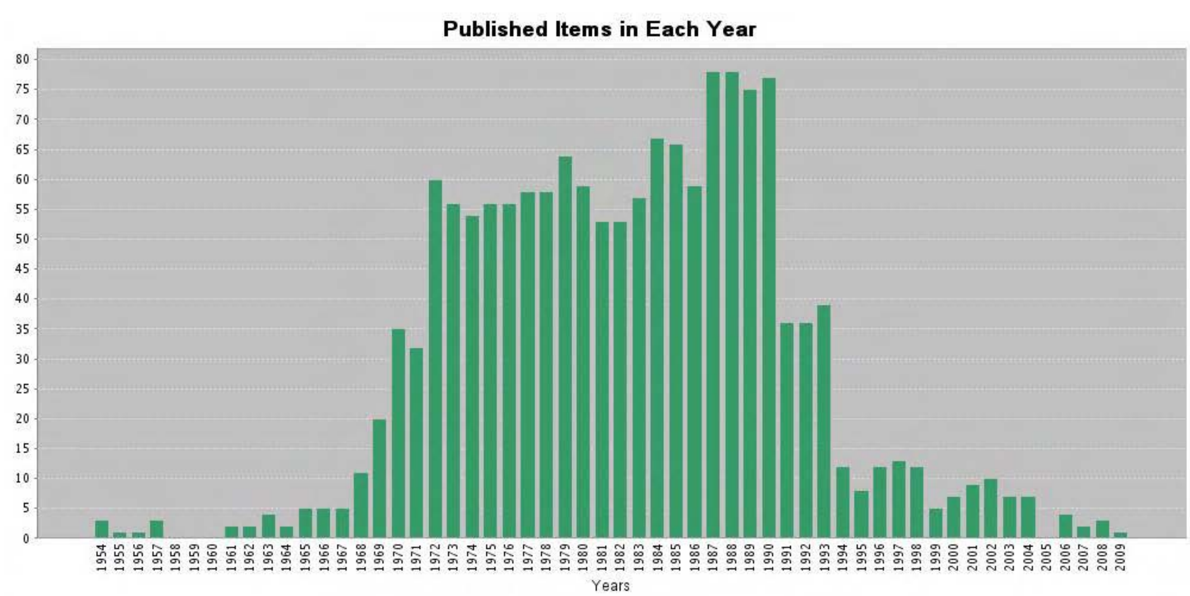


Fig. 7 — Master records for Garfield’s publications in the WoS database

For several of his other papers published, there are no master records in WoS because it did not cover the journal, such as *The Chemical Bulletin* that published Garfield's paper on Citation Indexes – New Path to Scientific Knowledge in 1956, or *Chemical & Engineering News* (until 1967) that had several contributions by Garfield before 1967.

The same is true for some conference papers, such as the one on A Unified Index to Science, a substantial paper published in the Proceedings of the International Conference on Scientific Information in 1959. There are no records for many of his letters to the editor written in the 1950s and 1960s.

Coverage of his papers becomes more complete from 1968 onward, reaching the zenith in the late 1980s and early 1990s when his yearly publications exceeded 70 papers per year. The only lasting and significant omissions are his book and book chapters, which are still not covered as source documents, therefore they don't have master records to attach the fairly large number of citations (close to a thousand) received by them, and are ignored in the generation of the Citation Report's metrics.

Overall, the graph shows a telling scholarly publishing pattern, starting a little earlier than usual, before age 30, when he published a seminal paper about citation indexing, then rising continuously, followed by a consistent, and unusually high publication rate/year of about 60 items, then rising further to and staying at the 75 papers/year rate. This was followed by a decline at age 65 (when many others retire) for about 3 years at a still very impressive 45 items/year phase (not exactly a lull), followed by a 20-items/year period for four years, then a 5-6 items per year phase, reduced to occasional papers in the past five years, when very few researchers would have the interest and/or ability to read, let alone to write.

Source base

As for the sources of publications, *Current Contents* has far the most of Garfield's papers. It includes 1,066 of his essays, commentaries, and other editorials (nearly 70% of all his publications), while of the discipline-specific editions of the *Current Contents* family, such as Life Sciences, Clinical Medicine, Social Behavior, Physical, Chemical & Earth Sciences, Engineering Technology & Applied Sciences, only the Life Sciences edition has records for his papers, but for 89 of them.

The second largest source is *The Scientist* which has 139 (9%) of his publications. The *Journal of the American Society for Information Science & Technology* (including its two preceding titles) is the third largest source for Garfield's publication with a total of 19 papers.

There is a remarkable cluster of highly respected journals where he has published 9-13 papers. These include *Journal of Information Science, Journal of Chemical Documentation, Nature, Science* and *Scientometrics*.

The next group also includes a number of high ranking medical, chemistry and engineering serials with 4-5 of his papers, such as *Annals of Internal Medicine, British Medical Journal, Current Science, Journal of the American Medical Association,* the *Canadian Medical Association Journal, IEEE Transactions on Professional Communications, ChemTech*, the *Journal of Chemical Information and Computer Science, Journal of Documentation, Proceedings of the ASIS(T) Annual Meeting*. There are more than 95 other journals and conference proceedings that have published 1-3 of his papers.

Subject areas

The wide subject domain of source journals that published Garfield's papers indicate both the interest in and relevance of his research about citation indexing and analysis, citation-based searching, as well as measuring the influence and impact of journals for the readership of a variety of academic journals in different disciplinary areas.

Of course, his Journal Impact Factor has been a controversial issue, and some of the citations to his papers about the impact factor, express disagreement with or reservation about the concept and/or its implementation, including two of my own earlier publications[23, 24]. However, many of the critical references should be directed to those who misuse the journal impact factor for purposes that it was not meant to be used for - in spite of Garfield strong warning against this practice[25,26,27].

Source Titles Refine Exclude Cancel Sort these by: Record Count

The first 100 Source Titles (by record count) are shown. For advanced refine options, use Analyze results .

CURRENT CONTENTS (1,066)	LIBRARY JOURNAL (2)	FEMS MICROBIOLOGY LETTERS (1)
SCIENTIST (146)	LIBRARY QUARTERLY (2)	FRONTIERS OF LIBRARIANSHIP-SYRACUSE UNIVERSITY (1)
CURRENT CONTENTS/LIFE SCIENCES (89)	NACHRICHTEN FUR DOKUMENTATION (2)	HEALTH INFORMATION AND LIBRARIES JOURNAL (1)
JOURNAL OF INFORMATION SCIENCE (13)	NATURWISSENSCHAFTEN (2)	INFORMATION SCIENTIST (1)
JOURNAL OF CHEMICAL DOCUMENTATION (12)	AACE BULLETIN (1)	INFORMATION TECHNOLOGY AND LIBRARIES (1)
NATURE (12)	ACS MISCELLANEOUS PUBLICATION (1)	INNOVATION AT THE CROSSROADS BETWEEN SCIENCE AND TECHNOLOGY (1)
JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE (11)	AMERICAN BEHAVIORAL SCIENTIST (1)	INTERNATIONAL MICROBIOLOGY (1)
ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY (10)	AMERICAN SOCIOLOGIST (1)	ISRAEL JOURNAL OF AGRICULTURAL RESEARCH (1)
SCIENCE (10)	ANAESTHESIST (1)	JOURNAL OF CERAMIC PROCESSING RESEARCH (1)
SCIENTOMETRICS (9)	ANNALS OF BIOMEDICAL ENGINEERING (1)	JOURNAL OF INFORMETRICS (1)
CURRENT COMMENTS (7)	ANNALS OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE (1)	JOURNAL OF NUCLEAR MEDICINE AND ALLIED SCIENCES (1)
ANNALS OF INTERNAL MEDICINE (5)	ARBOR-CIENCIA PENSAMIENTO Y CULTURA (1)	JOURNAL OF PUBLIC HEALTH DENTISTRY (1)
BRITISH MEDICAL JOURNAL (5)	ARCHIVES OF PATHOLOGY (1)	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY (1)
CURRENT SCIENCE (5)	ARCHIVES OF SURGERY (1)	JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION (1)
IEEE TRANSACTIONS ON PROFESSIONAL COMMUNICATION (5)	ASIS MONOGRAPH SERIES (1)	JOURNAL OF THE HISTORY OF THE BEHAVIORAL SCIENCES (1)
JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION (5)	ASIST 2003: PROCEEDINGS OF THE 66TH ASIST ANNUAL MEETING, VOL 40, 2003 (1)	JOURNAL OF THE INDIAN INSTITUTE OF SCIENCE (1)
JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY (5)	ASIST 2004: PROCEEDINGS OF THE 67TH ASIS&T ANNUAL MEETING, VOL 41, 2004 (1)	JOURNAL OF THE OPTICAL SOCIETY OF AMERICA (1)
CANADIAN MEDICAL ASSOCIATION JOURNAL (4)	BIOLOGIYA MORYA-MARINE BIOLOGY (1)	JOURNAL OF THE PATENT OFFICE SOCIETY (1)
CHEMTECH (4)	BIOSCIENCE (1)	LIBRI (1)
JOURNAL OF CHEMICAL INFORMATION AND COMPUTER SCIENCES (4)	BULLETIN OF THE ATOMIC SCIENTISTS (1)	MEDICAL JOURNAL OF AUSTRALIA (1)
JOURNAL OF DOCUMENTATION (4)	BUSINESS SOFTWARE REVIEW (1)	METHODS OF INFORMATION IN MEDICINE (1)
PROCEEDINGS OF THE ASIST ANNUAL MEETING (4)	CANADIAN JOURNAL OF INFORMATION AND LIBRARY SCIENCE-REVUE CANADIENNE DES SCIENCES DE L INFORMATION ET DE BIBLIOTHECONOMIE (1)	NEW ENGLAND JOURNAL OF MEDICINE (1)
AMERICAN DOCUMENTATION (3)	CANADIAN JOURNAL OF PSYCHIATRY-REVUE CANADIENNE DE PSYCHIATRIE (1)	NEW SCIENTIST (1)
SPECIAL LIBRARIES (3)	CANADIAN LIBRARY JOURNAL (1)	OCCUPATIONAL MEDICINE-OXFORD (1)

Fig. 8 — Excerpts from the list of journals where Garfield published

It is natural that the breadths of subject areas show the same interdisciplinary spectrum as the journals because journals are assigned to subject areas, not to individual papers for WoS records. It is to be noted that 9 of the 59 subject categories to which Garfield's papers were assigned, have the qualifier multidisciplinary or interdisciplinary added to the discipline, such as Chemistry, Interdisciplinary. It is also telling that the two most prominent subject areas of the journals where Garfield published belong to the broad Multidisciplinary Sciences category, and the one of Social Sciences, Interdisciplinary. Another, indirect, indicator is the fact that while records (actually journals) are assigned to 1.37 subject categories across the entire database, in case of Garfield, records of the journals that published his papers were assigned to 1.90 subject categories. True, in most of the categories, there are only one or two records for his papers, the width of the spectrum is remarkable.

Document types

The types of documents published also show a wide variety. More than half of them are articles, and the three other document types (proceedings paper, review and note) that belong to the "citable" documents category make up together 54.4 % of his publications that have a master record. The note type (used for short communications) is very low, but the reason for it may be that the use of this document type was stopped in 1997. It is another question, that many of the other, "non-citable" document types, especially, his 571 editorial materials (37.2%), did get cited, some very highly cited (that turned out from my analysis to be ill-attributed to some of his other papers, and ill-calculated from the perspective of the h-index and the ration of cited vs uncited papers, as will be discussed later.

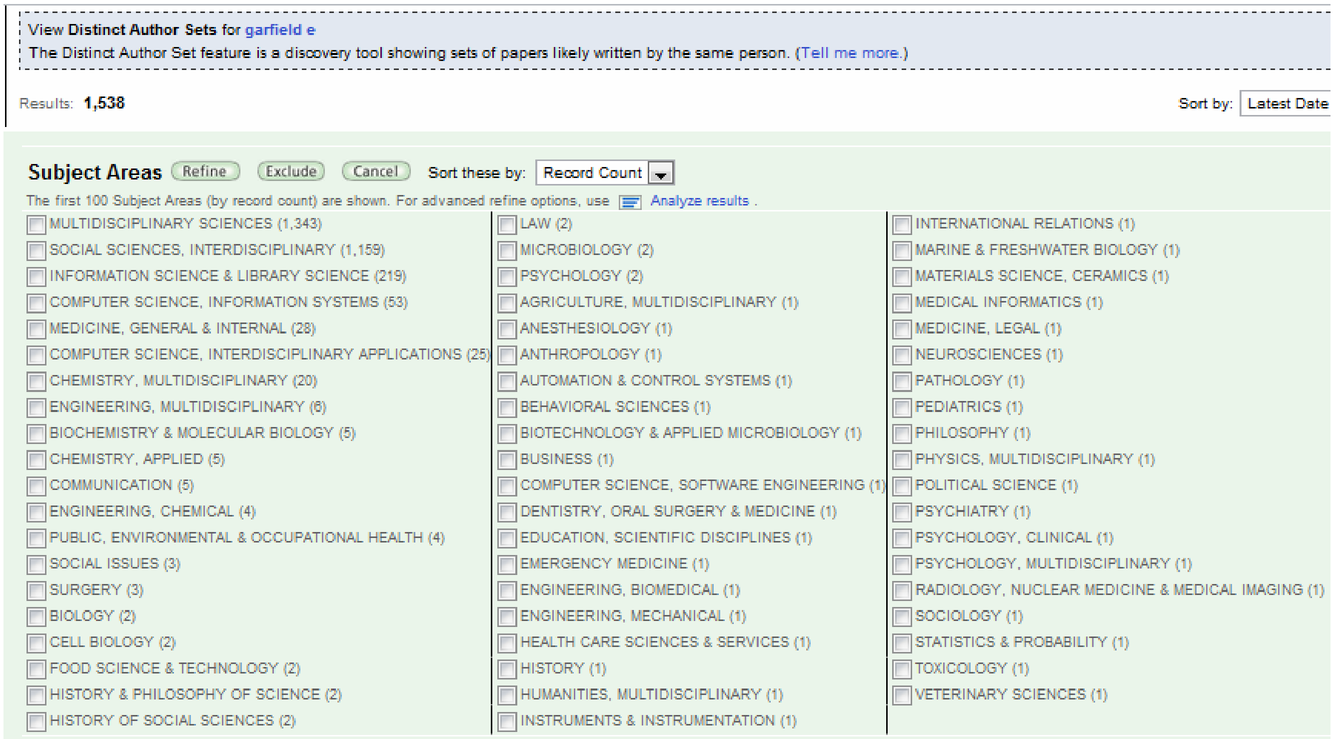


Fig. 9 — Subject areas of journals that published Garfield's papers

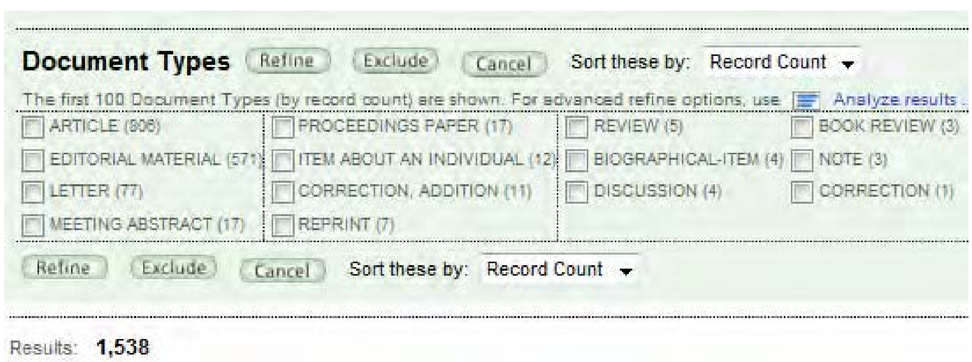


Fig. 10 — Document types of Garfield's papers

It is also worth noting that there are 16 items in the Biographical item, and Item about an individual categories – illustrating well that he has given credit to those he has worked with, or who had strong influence on him directly or indirectly.

Garfield's impact profile

The number of publications of research and teaching faculty and academic librarians has been one of the most important criteria in decisions related to tenure, promotion, and grant applications for decades. It was readily available from the curriculum vitae of the applicants, and easy to verify. The number of citations received has not been such a widely used criterion for several reasons. One of the reasons was that calculating the number of citations required access to the predecessors of the Web of Science database in print, CD-ROM or online formats.

Only select research centers and universities could afford the expense of the digital versions, and the number of highly skilled searchers who had enough experience with the advanced, and not user-friendly

search mode of the expensive Dialog, STN, and DataStar systems that made available significant part of the ISI Citation Indexes were few and far between. The CD-ROM version also required considerable skills for accurate results, and several yearly cumulative editions for the coverage of the required time span.

The print versions of the citation indexes were quite time consuming to use. Launching of the Web of Science database brought some essential change in the late 1990s and early 2000s, by offering user-friendly interface of some of the search and output features. The real breakthrough was the introduction of the Citation Report feature to WoS a few years ago. This exceptionally good and very practical feature automatically generates the quintessential metrics about the publishing productivity and the citedness of the publications of individuals, research groups, journals as long as the number of documents in the set to be analyzed does not exceed 10,000 records, the limit set by the developers of the Citation Report feature.

This limit is not a problem for the evaluation of the publishing profile of individuals as even the most published individuals are way below the 10,000 limit. It may be a problem for department level evaluation (but that can be avoided by aggregating individual-level data), and journals, unless a relatively short period is used.

The publish, get cited or perish era

There is clearly a tendency to move away from the evaluation based on the publish-or-perish mantra in evaluating the productivity and influence of researchers to the more complex, combined measures of the publish-get-cited-or-perish mentality. This is understandable for research faculty and staff, but not for applicants whose primary forte should be the quality of teaching and service.

The Citation Report includes the total number of citations received by all the items in the result list. Creating the appropriate result list still requires careful browsing of name indexes and defensive search strategy, which contemplates and handles the problems of homonyms, inconsistent use of a single or multiple middle initials, hyphens and other special characters in the last name.

Fortunately, in the case of Eugene Garfield, there are no such concerns as he has been using a single first and last name, and –in the WoS database- there are no other researchers with a first name starting with the letter E, so the query Garfield E retrieves only records for Eugene Garfield as an author or co-author. This is not the case for the functionally same query in Scopus and Google Scholar even when exact matching is specified. Their results still include records for papers that were written by RE Garfield, AE Garfield, EN Garfield and a dozen other authors whose first and/or middle initials include the letter E – even if the query is put in between quotation marks.

The Citation Report provides aggregate citation statistics for the search results. The total number of citations include all citations received by the papers of the author – as long as the cited reference matches exactly not only the format of the specified author's initial(s) and last name, but the bibliographic details of the publication, specifically the name of the journal, its volume number, the year of publication, and the starting page number of the cited document. Any difference would make the reference a "stray citation" This is not a term that you would find in the literature, neither is its counterpart, "orphan citation" so they are explained and illustrated in two papers[28,29], and are discussed and illustrated only shortly here. Figure 11 shows an excerpt from the cited reference index list of WoS with valid and stray references to Eugene Garfield's publications.

The first entry shows a stray reference as it is incomplete not having a starting page number that is required for identifying a specific publication. The second and third entries are valid, they could be matched against the record for two short editorials that could be matched to a master record. The third one is a stray reference because it misses the volume number, and adds an invalid identifier after the journal name because all the data elements. The fifth one is also a stray reference because the journal is spelled in the reference as Scientists, i.e. in the plural format. The reference to a book or any other documents that has no master records becomes an orphan citation, no matter how complete and perfect is the reference in every regards. This happens to the most cited publication of Garfield, to the book about Citation Indexing that was cited more than 900 times in sources covered by WoS, but all of them become orphan references because of the lack of a master record.

CITED REFERENCE INDEX
References: **1 - 5 of 5**

Page 1 of 1 Go

Select Page | Select All* | Clear All | Finish Search

Select	Cited Author	Cited Work [SHOW EXPANDED TITLES]	Year	Volume	Page	Article ID	Citing Articles **	View Record
☐	GARFIELD E	SCIENTIST	1995	9			1	
☐	GARFIELD E	SCIENTIST	1995	9	11		3	View Record
☐	GARFIELD E	SCIENTIST	1995	9	13		4	View Record
☐	GARFIELD E	SCIENTIST 0515	1995		12		1	
☐	GARFIELD E	SCIENTISTS	1995	9	19		1	

Select Page | Select All* | Clear All | Finish Search

Fig. 11 — Excerpt from the Cited Reference Index

The consequence of this is that such citations are ignored in calculating the total citations received by the individual items. They are also ignored in calculating the cumulative total which is created by summing up the citations received by each paper represented by the by the bibliographic master record. This has serious implication for almost all of the metrics reported in the Citation Report, that will be discussed below. Suffice it to state here, that all the numbers and indicators in this paper are based –unless explicitly mentioned- on citations that exactly match the above mentioned bibliographic details that appear in the master record created for the papers of Eugene Garfield.

In cases where the master record contains an error, such as a misspelled last name, initial(s), publication year, volume, and starting page number, all the correct citing references will be ignored, and the master record would not show any correct citations received by the paper. If there is no master record for a paper in WoS for whatever reason, the cited reference becomes an orphan (or orphaned) reference/citation, and is ignored in computing the citations received by the paper, its author, the author's institution and country. Even with these limitations, the metrics are very informative, but they are deflated - to different extent.

Garfield's realistic impact factor and citedness rate

Eugene Garfield's total number of citations received to his 1,538 publications as reported by WoS was 6,491 (from 4,031 papers) as of mid-June – including self citations. This yields an average of 4.22 citations per paper published.

The dispersion of the citations, of course is very high. Seemingly, 305 papers (20% of his publications) gathered all the citations, in other words 80% of his works appears to have remained uncited.

However, this is not the case. This citedness rate is based only on those references that exactly matched the master records by last name, initial, publication year, volume number and starting page number.

The reality is that there are about 7,000 additional references to Garfield's works in publications covered by WoS. However, these are stray or orphan references that could not be credited by the citation matching algorithm to the master record of the work because of the non-exact match, or because the publication did not have a record in the master file to gather the citation(s) received. It would require an

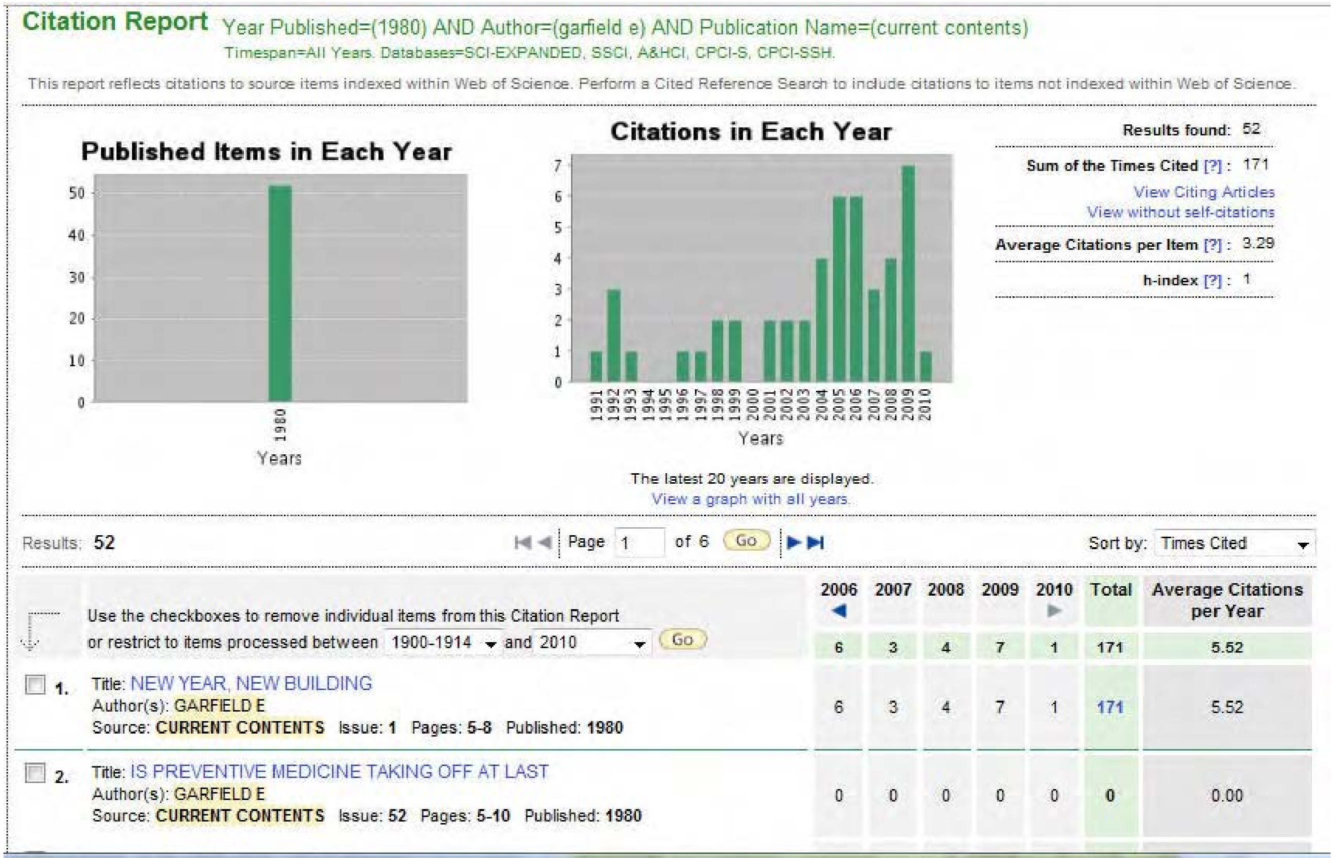


Fig. 12 — Single item is awarded all the citations received by any of the papers in a given year between 1973 and 1988.

arduous work for a skilled information professional, familiar with Garfield's works to pair up those stray (inaccurate and/or incomplete) references with the master records, and to create pseudo master records for the orphan citations to gather the references that cite the specific work.

Still, at the broad level, this means that Garfield received nearly 13,500 citations for his ouvre. Considering that some of his journal and conference publications don't have a master record, and none of his books, and book chapters have, although they are cited, some of them very highly, his average citedness rate would more than double to 8.65 citations if the total number of his published works is estimated to be around 1,560 items.

The ratio of his cited versus uncited works would also raise significantly, because the stray and orphan references are likely to cite works that were in the group of uncited publications, uncited that is by perfectly matching references. This can be only guesstimated because a large portion of those 7,000 stray and orphan references is assumed to cite works which have been already in the group of publications that were cited at least once by perfectly matching references.

Even if the orphan and stray references are ignored, the absolute number of citations received is remarkably higher than those of the top researchers in Garfield's central search areas: citation analysis, citation-based searching, bibliometrics, scientometrics and informetrics.

A special case for mismatching

There is another, presumably unique reason that the ratio of Garfield's cited vs uncited publications is likely to improve significantly. I presume that this case is unique because there is hardly any other author who would have published papers for decades in the same journal starting on the same page year after year.

This is the case for a large majority of his editorial essays, short articles and commentaries published in *Current Contents*. Most of these items started on page 3 or page 5. The author and journal name were always the same. The publication year remained the same within a year. The titles of the papers of course, were different, but this field is not used in citation matching. There was issue number but no volume number in the records created in WoS for items taken from *Current Contents*.

However, for citation matching the volume number is used. Here is a sample result list for the 52 papers of Garfield in the 1980 volume of *Current Contents* sorted by times cited to illustrate how the display format of the records look like, and how a single paper in a given year is credited with all (or sometimes almost all) of the citations received in the specific yearly volume, irrespective of the actually cited paper.

How could the editorial about the new building of the Institute for Scientific Information gather so many citations, but the 51 other items about the much more likely citable topics of preventive medicine, the British Library, lactose intolerance, ulcer, leprosy,

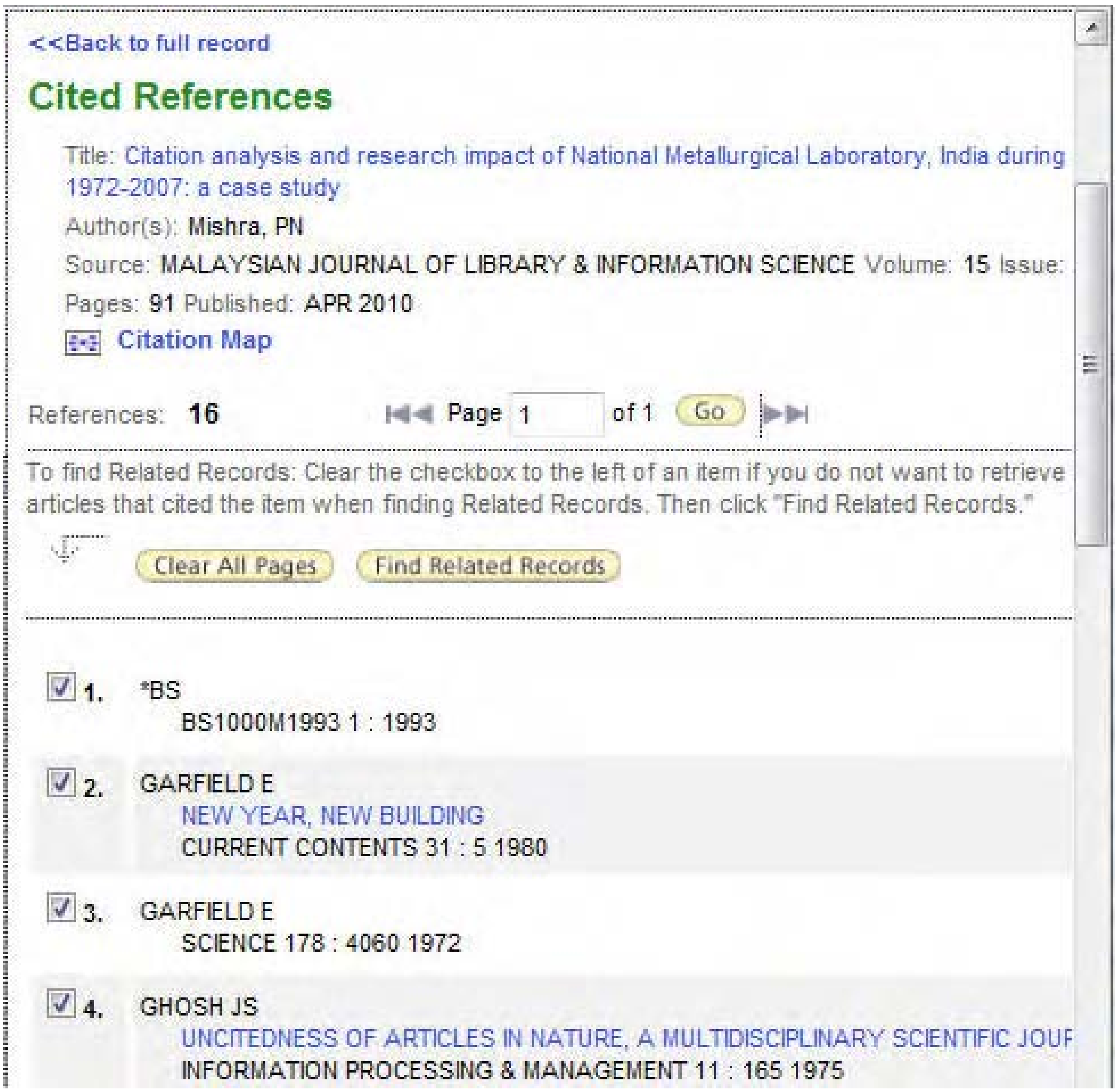
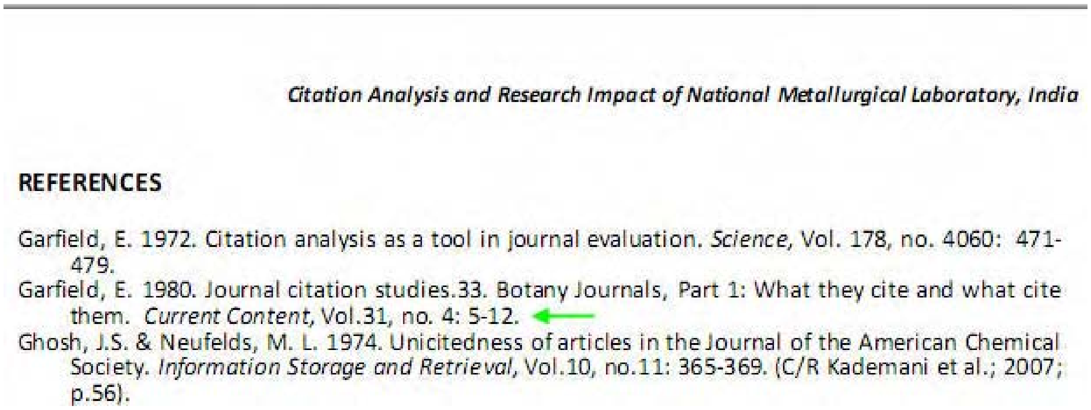


Fig. 13 — Mis-credited citation to an unrelated editorial due to citation mis-match by the software

cluster mapping, citation amnesia, dyslexia, or citation pattern of botany journals not a single citation? The answer is erroneous citation matching.

Here is a current example when a paper published in April 2010, purportedly and unlikely cited the New Building, New Year editorial


Citation Analysis and Research Impact of National Metallurgical Laboratory, India

REFERENCES

Garfield, E. 1972. Citation analysis as a tool in journal evaluation. *Science*, Vol. 178, no. 4060: 471-479.

Garfield, E. 1980. Journal citation studies.33. Botany Journals, Part 1: What they cite and what cite them. *Current Content*, Vol.31, no. 4: 5-12.

Ghosh, J.S. & Neufelds, M. L. 1974. Unicitedness of articles in the Journal of the American Chemical Society. *Information Storage and Retrieval*, Vol.10, no.11: 365-369. (C/R Kademani et al.; 2007; p.56).

Fig. 14 — The hijacked reference

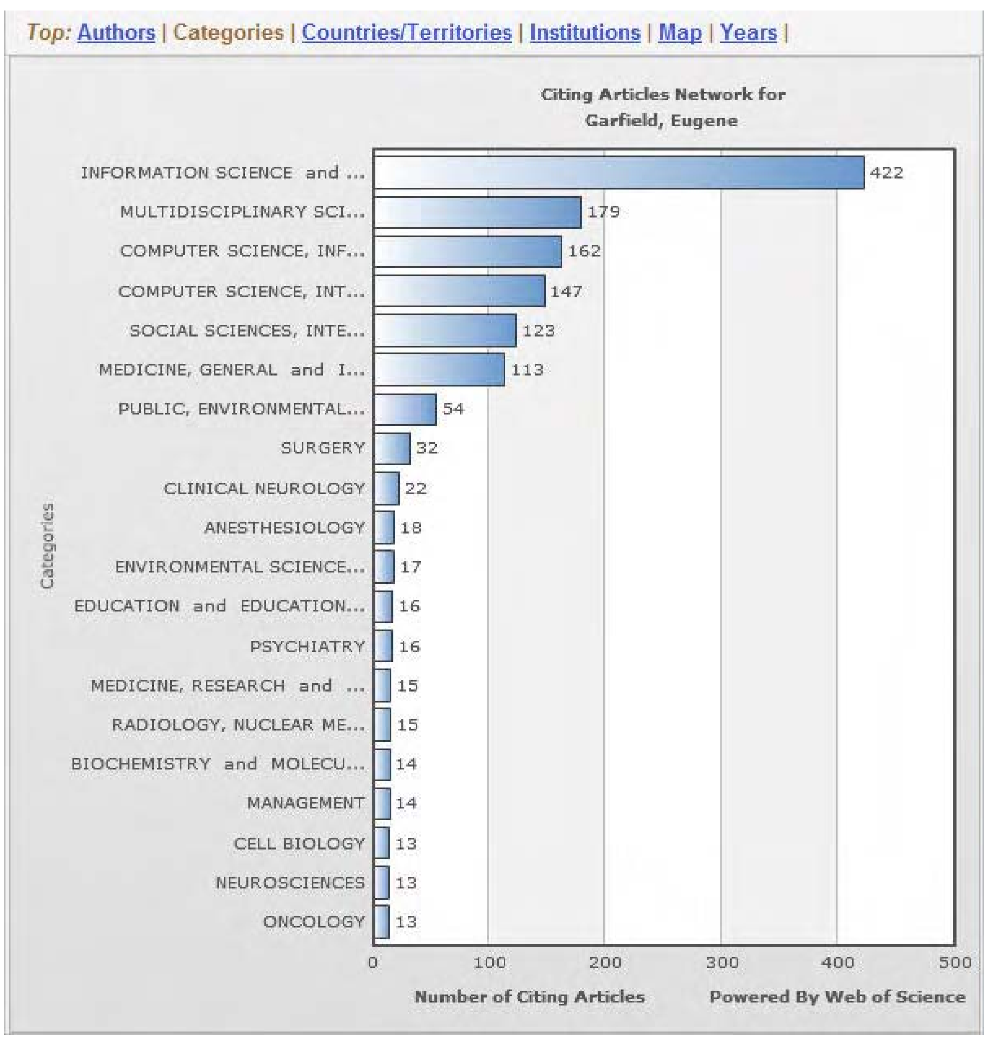


Fig. 15 — Citations received by subject category according to ResearchID

In this case it was easy to corroborate the citation mismatching error by looking up the open access document that clearly shows what was the really cited editorial

The same or very similar symptom can be seen for all the volumes between 1973 and 1988, distorting the citedness of several hundred papers, but not since 1989. Why? Because from 1989 the issue number which could be the distinguishing data element for the citation matching (but it is not the one that is used) is entered in the volume field, which is an element in the citation matching.

This not muck raking. There are about thousand papers of Garfield that are potentially deprived from one or more citations. Redistributing the citations using the same trick as apparently was used since 1989 would give credit where credit is due, and would dramatically increase, the ratio of cited versus uncited items from 20 vs 80 to almost 70 to 30 in my very preliminary estimate.

Citings by subject areas

Not surprisingly, papers discussing information and library science issues cite far the most often Garfield's papers both according to the ResearchID graph, and the WoS matrix. But the ranking of the citations by subject categories is quite different between the two. Again, it is not only the rank orders that differ but also the number of citing articles, quite significantly in spite of the minimal differences between the overall similarity of the basic indicator values of the two methods.

In my test papers published in Information and Library Science journals cited Garfield the most extensively, followed by journals in two computer science categories.

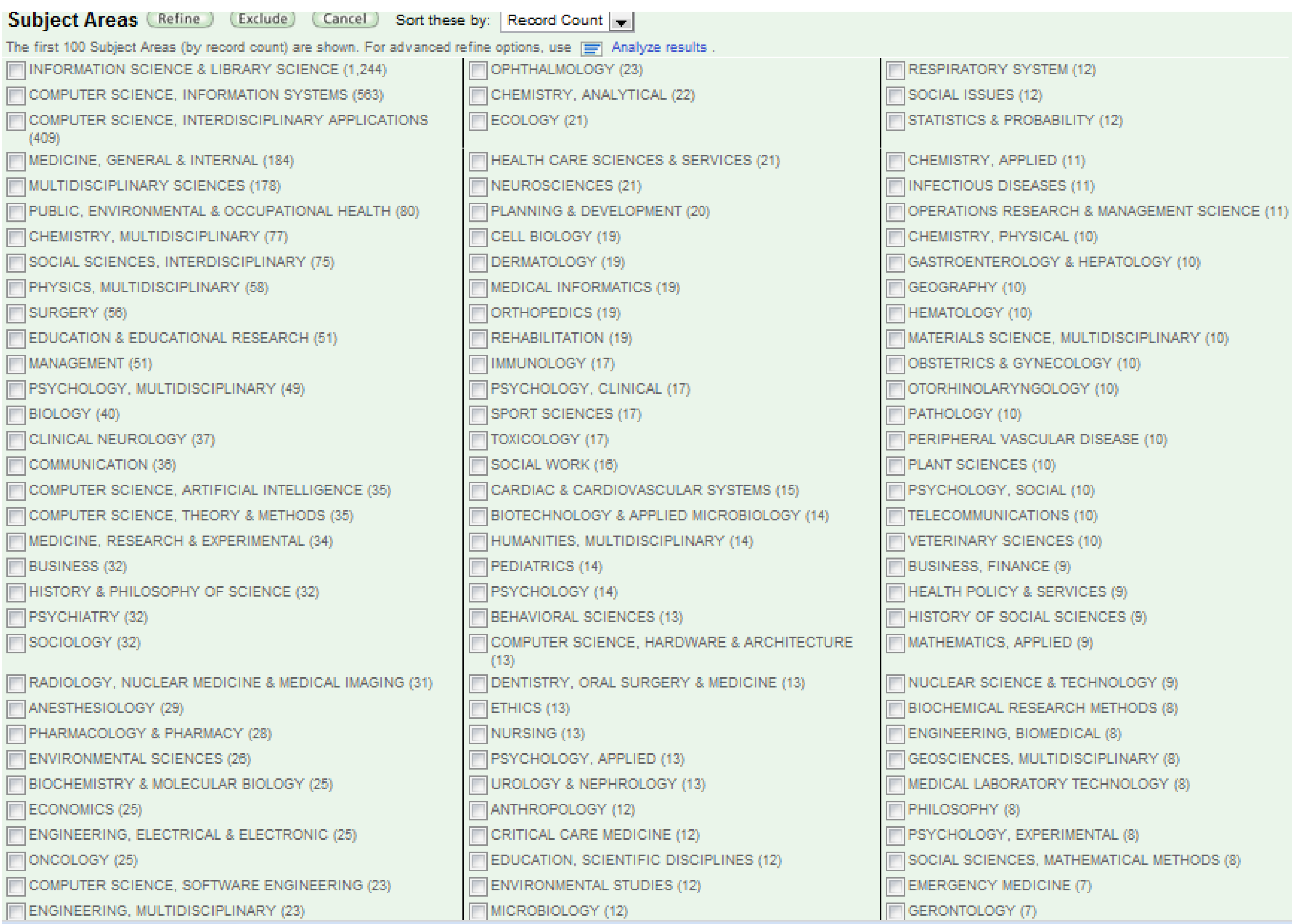


Fig. 16 — Citations received by subject category according to my test

Impact by citing sources

This chart reinforces the findings by the subject categories distribution of citations at the journal article, review and proceedings level. It clearly shows not only the dominance but also the variety of information and library sources, and more importantly the strong presence of many of the most influential, highest impact factor periodicals of the discipline.

Citing authors

The impact of Garfield's works is well illustrated by the number of authors who cited him. Obviously, Garfield himself must be excluded from the list even if in WoS, in the Journal Citation Reports, and in other special compilations, self-citations are not disregarded.

Of the 4,031 citing articles, 925 were authored or co-authored by Garfield, representing a reasonable 23% self-citation rate, but I removed self citations from all the sets.

The remaining 3,077 papers were authored or coauthored by about 4,200 researchers (yielding a 1.36 author per paper rate). Although there are 4,255 author names citing Eugene Garfield works in WoS, some are corporate names, some are identified as [ANON] for anonymous contributions, and several are different variations and punctuations of the same author.

The list includes the most respected scientometricians (both active and now retired ones) as the highest citers of Garfield (Jan Vlachy , Loet Leydersdorff, Ronald Rousseau, Henry Small, Anthony Cawkell, Henk Moed, Ron Kostoff, Francis Narin, Schubert Andras, Braun Tibor, Wolfgang Glanzel, Kathy McCain, Mike Thelwall, Michel Zitt, Juan Campanario, Hans-Dieter Daniel, Lutz Bornmann, Blaise Cronin, Charles Oppenheim, Matthew Falagas, Birger Hjorland, Felix de Moya-Anegon, and Concepcion Wilson to name some of those who cited Garfield at least in 10 papers, (and whose papers I have used often to learn about bibliometrics) . Moya-Anegon would appear much

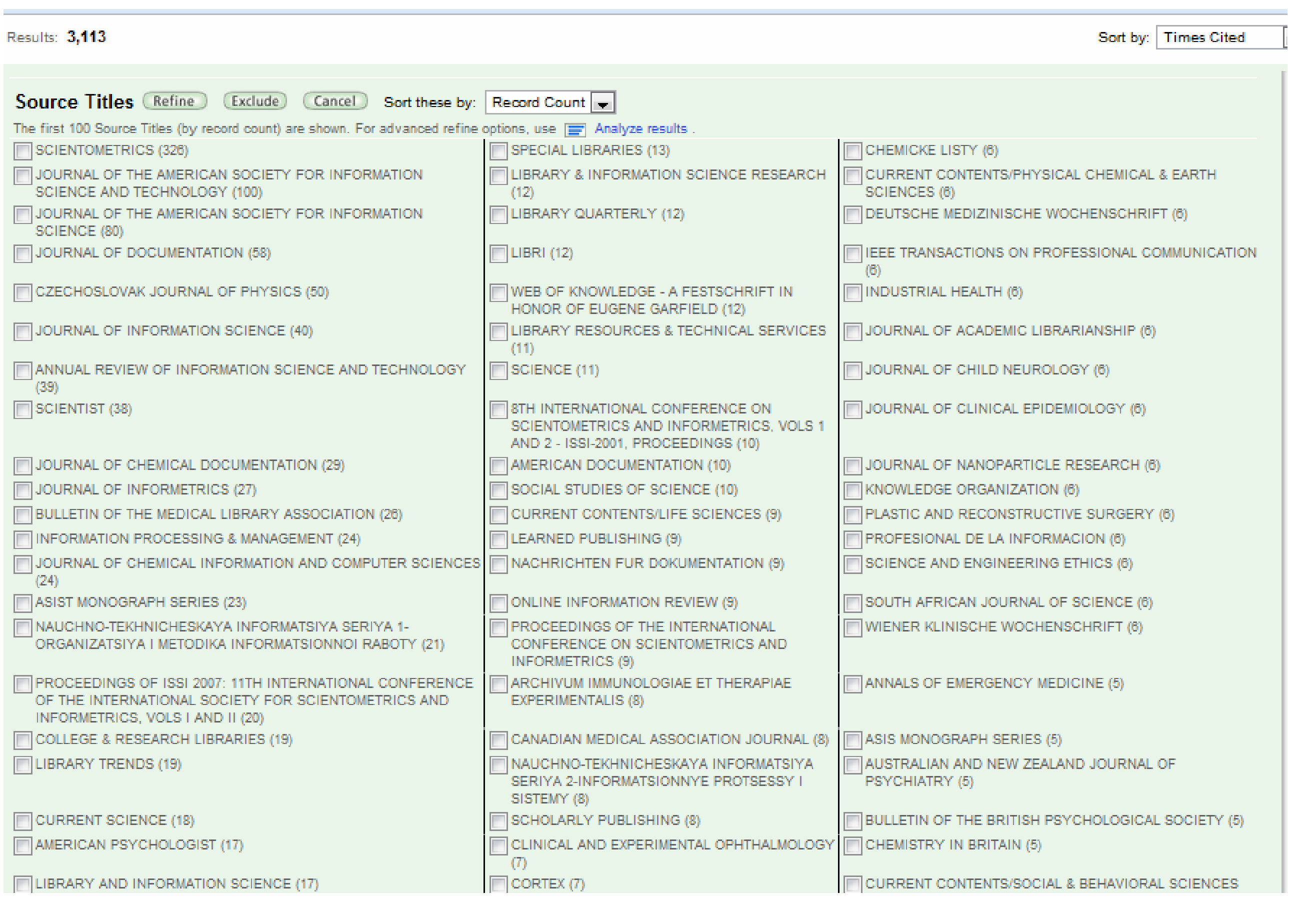


Fig. 17 — Periodicals that most often cite the works of Garfield

Fig. 18 — Teaching and research faculty members most often citing Garfield

higher on the list, but 10 of his papers are assigned to Felix de Moya-Anegon, and 8 to Felix Moya-Anegon, the same researcher.

The next category of top citers are also widely known specialists. The list clearly shows a perfect mix of the past, current and future generations of leading scientometricians. Some researchers cited Garfield “only” 3-5 times like Maurice Line, Gerard Salton Robert Merton, Steve Harnad to name a few, but their citations would count more than the average (if WoS would use a weighting algorithm in calculating citations and impact factors) as they were and are key figures in library and information science and computer science, respectively. Representatives of the he future generations of scientometricians also appear on the list, including the most promising ones, such as Lokman Meho, and Paul Wouters.

Once again, many Spanish, Portuguese, Dutch, Belgian, German, Italian, and French sciento-metricians appear with different name formats in WoS, that’s why the reported total number of authors, and the listed top 100 ones should not be taken at face value.

Very strangely, the ResearherID badge of Garfield reports much lower article numbers next to the name of the researchers citing Garfield, and some names are entirely left out that no time span limitation or other

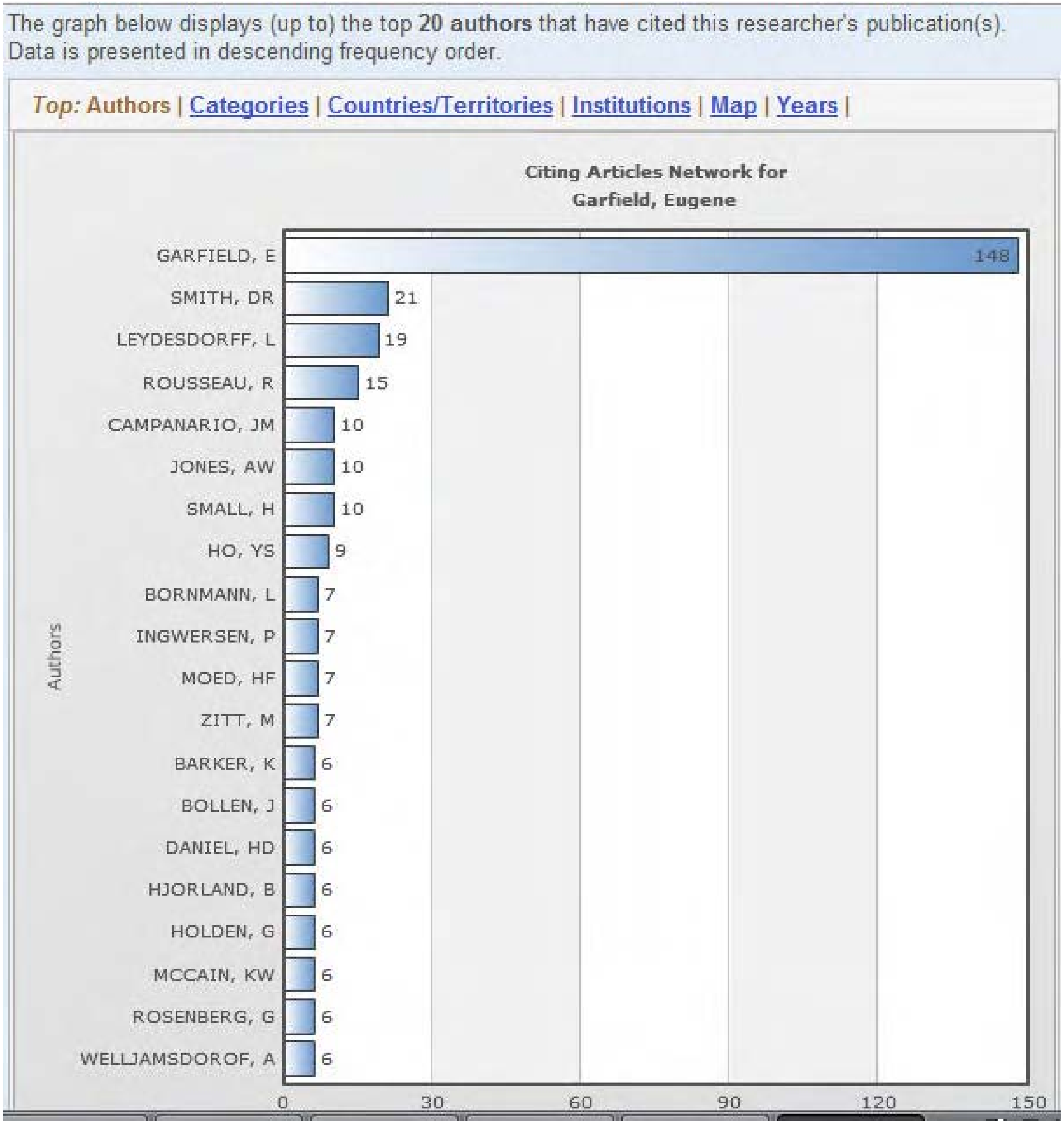


Fig. 19 — Top 20 citing authors of Garfield's papers in ResearcherID

search filter can explain. It is unfathomable how Narin, Cronin, Schubert, Braun, Glanzel did not make it to the top 20 list of Garfield citers in ResearchID. Creating the top list based on the citations of only the past ten or twenty years does not explain the differences.

Citings by Institutional Affiliation

There are 1,647 institutions whose authors have cited Eugene Garfield's works. The real number is somewhat less for reasons explained below, but even a 1,500 institutional base is large enough to indicate the worldwide reach and impact of Garfield.

It must be borne in mind that about 12% of the records have no institutional affiliations. In light of the top author lists produced directly from WoS, it is no surprise that the institutes with the best scientometric research centers and most influential experts are leading the list of affiliations most often citing Garfield.

They are informally referred to as the Bloomington, Philly, Copenhagen, Granada, Budapest, Leiden/Leuven (or Flemish) groups, and have much higher representation than the list would imply, because of the scattering of organizational affiliation names due to name changes, spelling and abbreviation differences, such as Inst Sci Informat (30) vs Inst Sci Information (11), Leiden Univ (26) vs Univ Leiden (9), Hungarian Acad Sci (23) vs Hungarian Acad Sci Lib (9) vs Lib Hungarian Acad Sci. It must be also emphasized that not all the records have information about the authors affiliation, which is made clear in this chart of ResearchID. From my set 386 records (about 12.5% of all the citing papers excluding self citations) had no author affiliation.

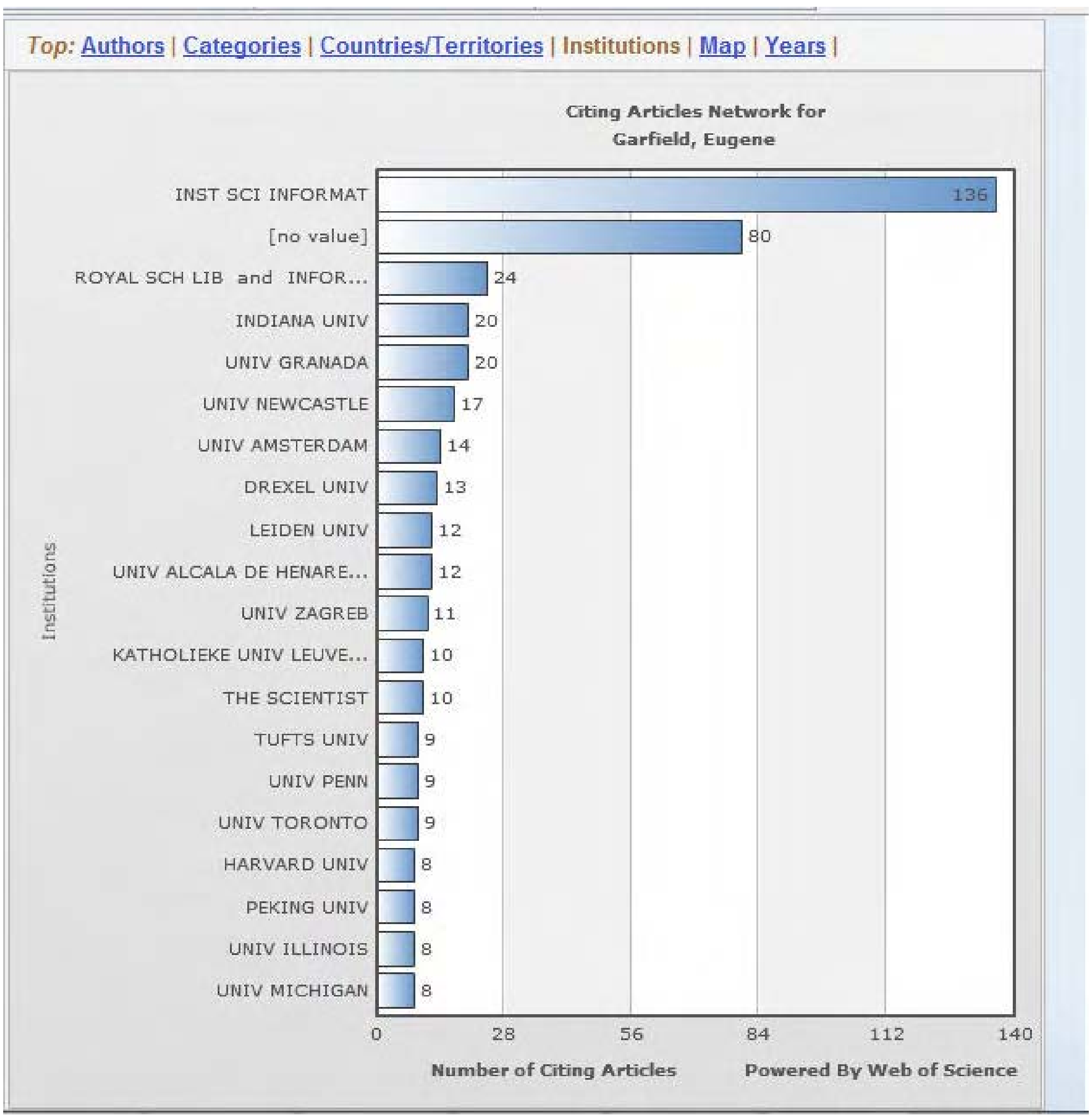


Fig. 20 — Top 20 Institutional affiliations of authors most citing Garfield according to ResearcherID

Once again, there are remarkable differences between the two charts in terms of the ranking and the hit counts of the institutions.

Citing country affiliation

The list of country affiliation of authors citing Garfield's publications looks like the itinerary of 80 Days Around the World. There are authors from more than 70 countries, (depending on how formerly separate but now united, and formerly united but now separate countries are counted, like Germany and Czechoslovakia) who have cited one or more of Garfield's papers at least once. Of course, these only represent the journals, conference proceedings, and monographic **series** such as Lecture Notes of Computer Science (LNCS) covered by WoS, but not monographs, or chapters from edited books.

ResearcherID clearly indicates that 71 papers had no country affiliation in its set. In my set, country data was available for all but 16 records, a very significant difference considering that I had a set of 3,113 items – excluding self-citations. Spain's high ranking is not surprising as the country has launched a very promising inter-university cooperation initiative that apparently motivated and helped researchers to do many co-operative research project and publish them in high ranking, English language journals.

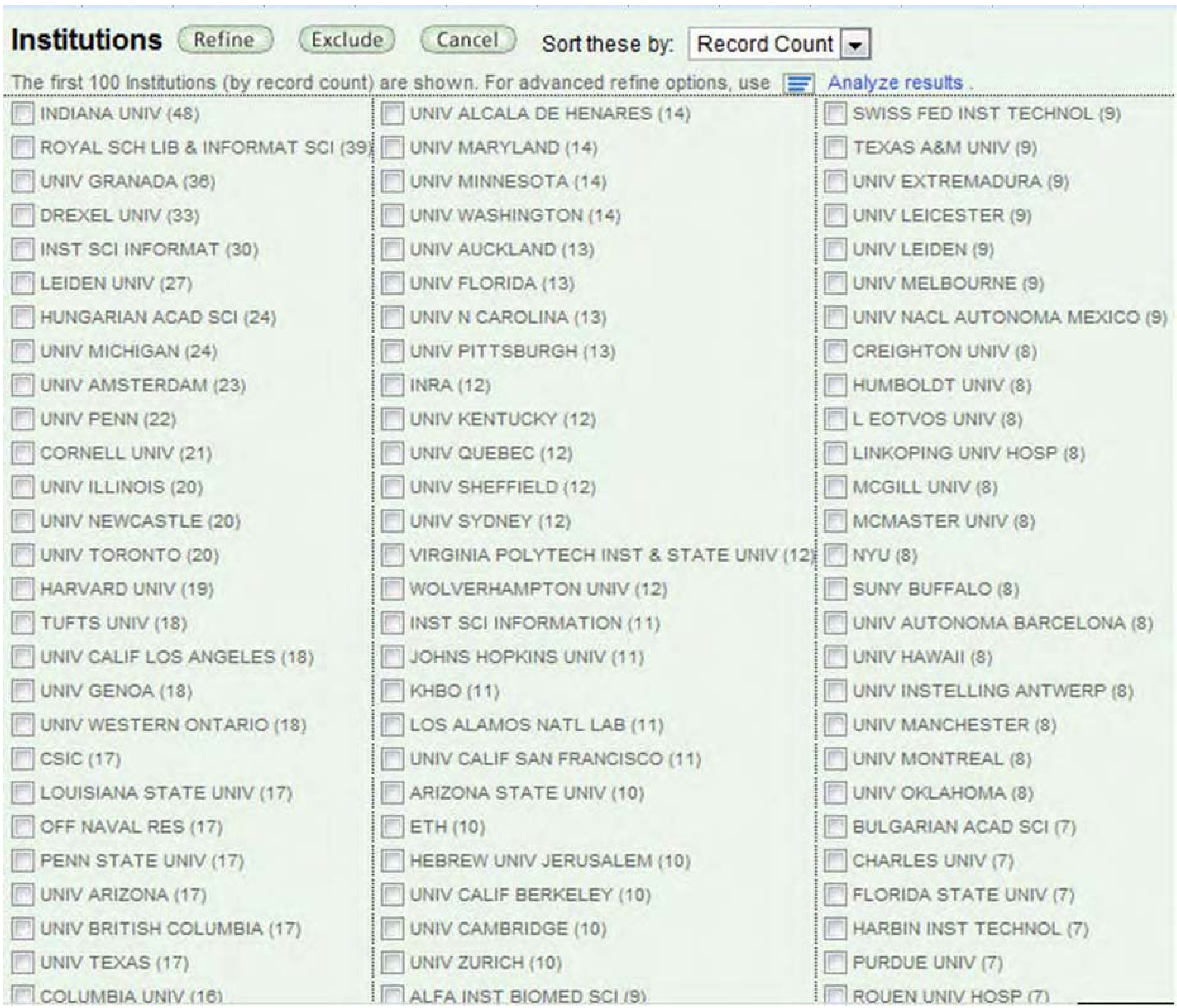


Fig. 21 — Institutions citing Garfield's paper the most often

Citing papers by language

The language of 91% the citing papers is English. This is no surprise as the vast majority of citers are from the U.S., U.K., Canada, and Australia. There are citers also from countries where English is an official language. In addition, it is well known and Garfield repeatedly emphasized[30-32] that English is the lingua franca of science, so anyone who does research of international interest must learn to publish in English, no matter how painful it is for us, ESL authors, Language was available in all the records in my set.

Spanish and German are the dominant languages of the non-English publications that cite Garfield, representing 28% and 24%, respectively. French and Russian make up 13 and 14%, and Japanese, Czech and Portuguese, make 7, 5 and 3% of the non-English subset of the citing publications.

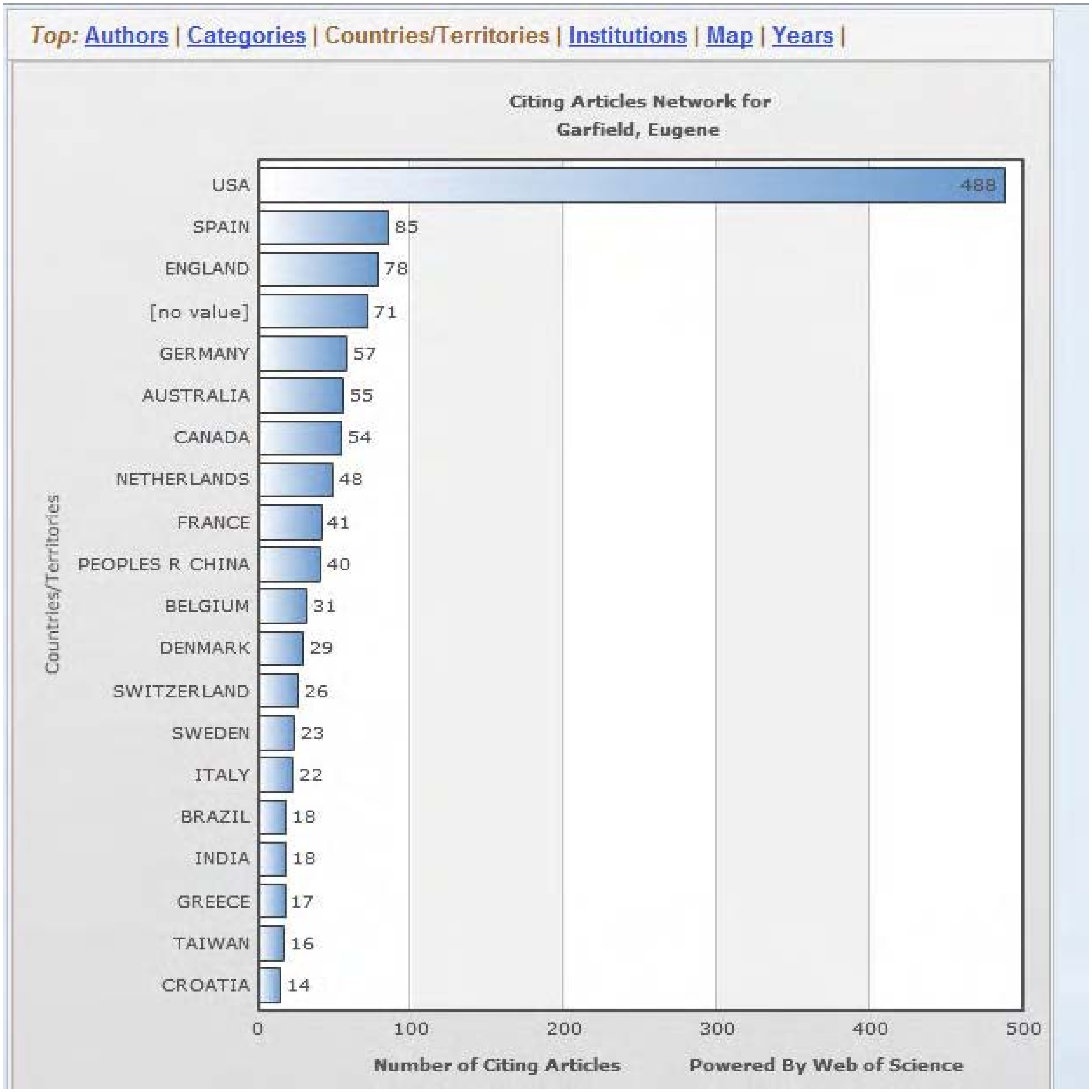


Fig. 22 — Distribution of citations received by Garfield by country according to ResearcherID

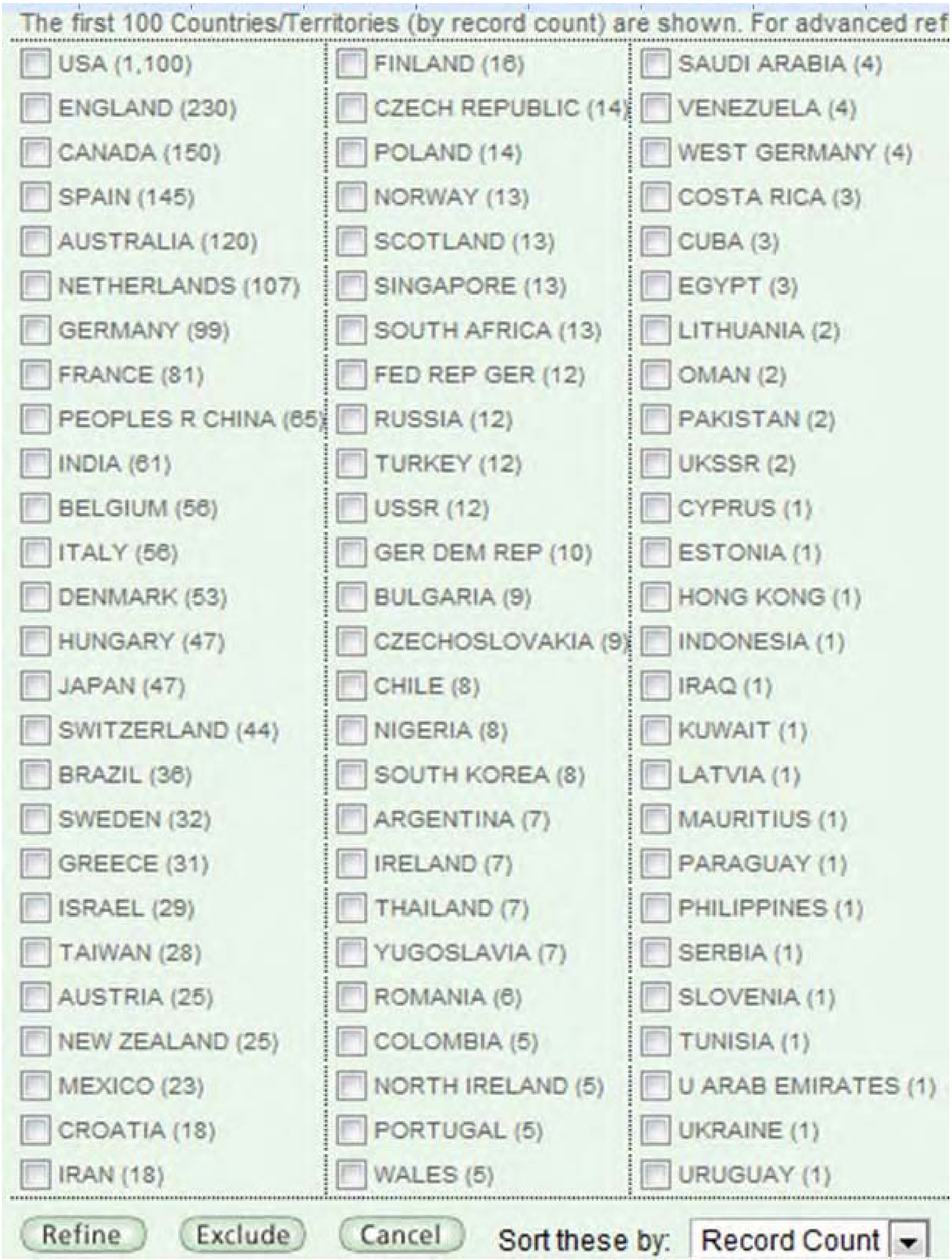


Fig. 23 — Distribution of citations received by Garfield according to ResearcherID

Garfield's h-index

The most favored single number indicator these days is the h-index and one or more of its derivative(s). It is indeed a potentially useful indicator reflecting both the productivity and the citedness of the researcher. Eugene Garfield has a h-index of 35 as reported by WoS both directly in my test and through ResearcherID, in mid-June, 2010. This is far the highest h-index in the field of information and library science, the primary target audience and citing group of Garfield. It reflects his scholarly stature very well.

The most striking aspect of his scholarly impact is the cumulative number of citing publications that rose to 4,038 the day I submitted my manuscript. I tried to express this progress in the cumulative chart in Fig. 25. The increase in 2007 of the total number of articles that cited his papers that year from 148 to 214, clearly indicates the renewed interest in his original idea about the impact factor in light of the emergence of similar indicators. At this pace it is quite possible that his yearly citedness by the end of 2010 will reach a new record exceeding 250 citing papers per year. Add to this the fact that many of the citing articles cite more than one of his publications in a single paper.

Fig. 24 — Distribution of papers citing Garfield by language

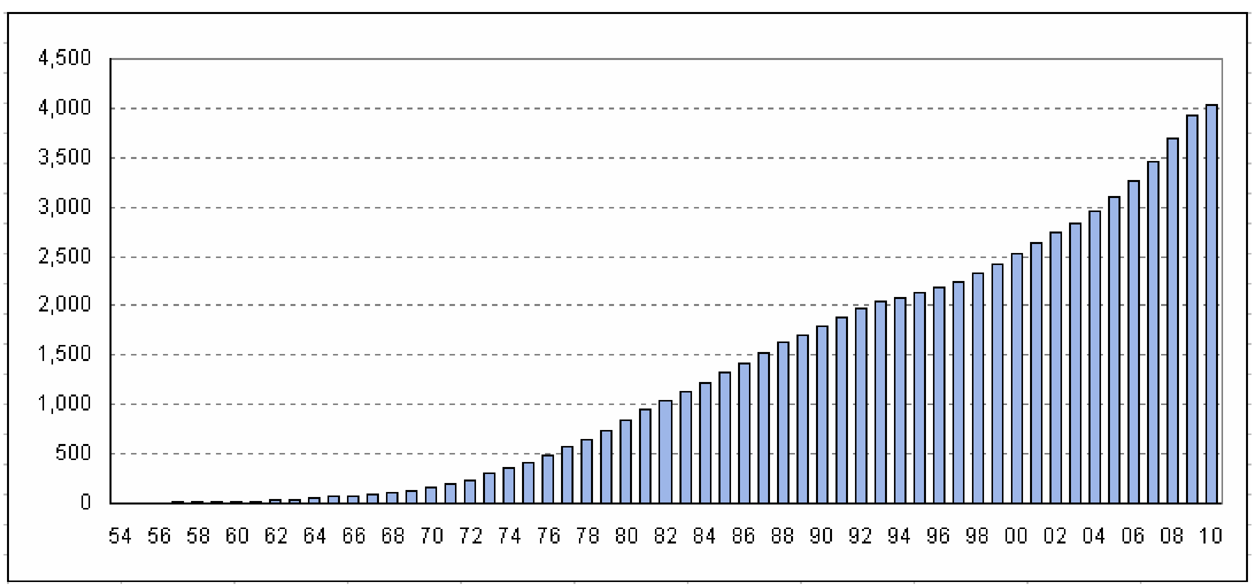


Fig. 25 — Cumulative number of publications citing Garfield's publications

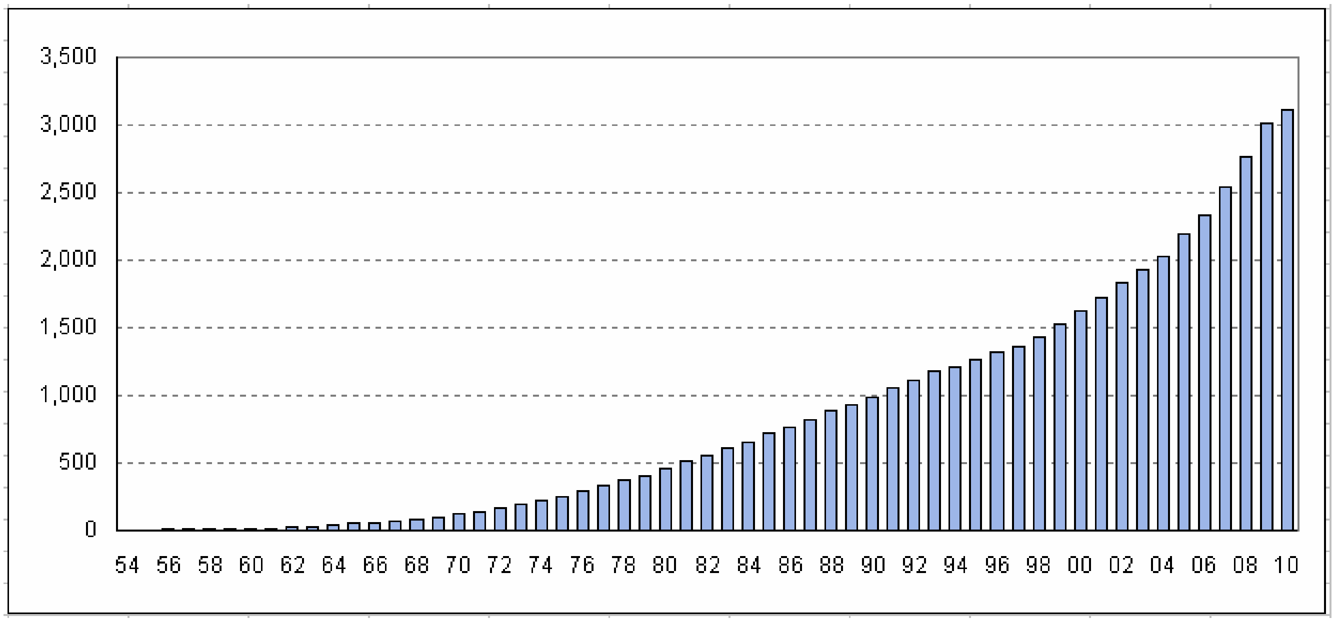


Fig. 26 — Cumulative number of publications citing Garfield's publications - without self citation

True this figure includes self-citations but it is at a very reasonable rate at slightly above 20%, which is common at his productivity level. Even without self-citation he has been cited by 3,113 papers of other authors. Considering the typical multiple authorship rate, once again this is just a baseline for appreciating his impact.

The very tangible rise of his influence is gratifying to see in his 55th year of publishing. Yes, it can be made even more gratifying if WoS would cover more sources, and would facilitate to add the stray and orphan references to master records, but even in its current format it provides an unparalleled resource for measuring the long term impact of an outstanding scientist and educator who shaped the thinking of many others for five decades. In case of Eugene Garfield, his philanthropy – along with his renaissance life style and work style, has added much to the scholarly impact, and I salute him on his 85th birthday, wishing good health and more citations.

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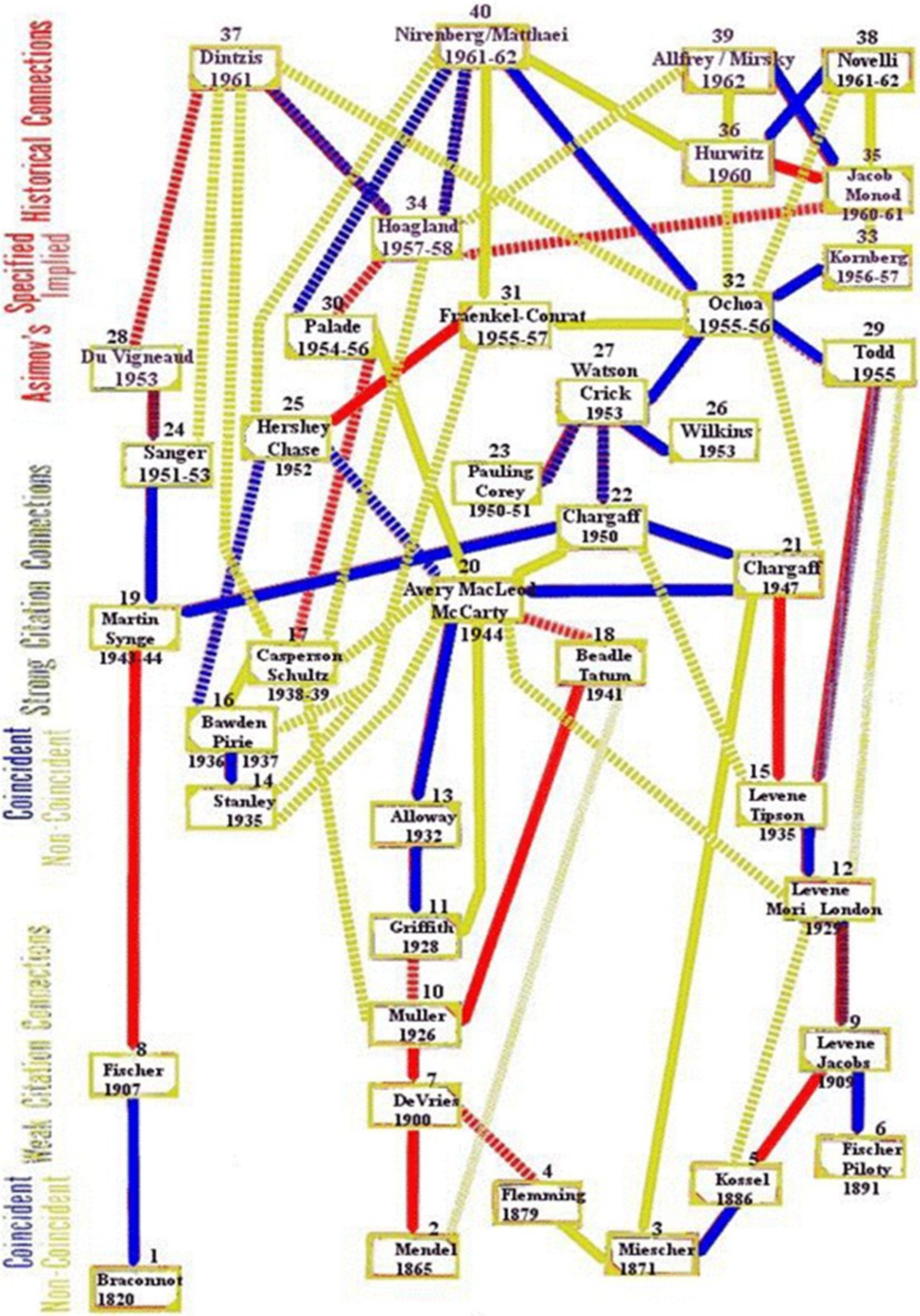
Co-Words, Co-Authors, and Journal Names



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